MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Professor R. A. Sampson, M.A., D.Sc., F.R.S., PRESIDENT, in the Chair.

Mary A. Blagg, Greenhill, Cheadle, Staffordshire;
Ella K. Church, Moormead Shaw, Ashtead, Surrey;
A. Grace Cook, The Rookery, Stowmarket, Suffolk;
Frederick Charles Leonard, President of the Society for Practical Astronomy, 1338 Madison Park, Chicago, U.S.A.;
Percy Austin Openshaw, B.A., Headmaster, Belmont, Lee Terrace, Blackheath, S.E.;
Ludwik Silberstein, Ph.D., Lecturer in Natural Philosophy in the University of Rome, 4 Anson Road, Cricklewood, London, N.W.;
Julius F. Stone, President of the Seagrave Company, Columbus, Ohio, U.S.A.;
Irene Elizabeth Toye Warner, Ardagh, Horfield Common West, Bristol; and
Mrs. Fiammetta Wilson, c/o Pioneer Club, 9 Park Place, St. James' Street, S.W.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Joseph Mason Baldwin, M.A., D.Sc., Acting Government Astronomer for Victoria, Observatory House, South Yarra, Victoria, Australia (proposed by A. S. Eddington);
Rev. Peter Davis Morse, L.T.S.C., Llain Cant, Wolf's Castle, S.O., Pembrokeshire (proposed by W. Phillips); and
Arthur Strachan, 30 Tregonwell Road, Bournemouth (proposed by E. Walter Maunder).

Sixty presents were announced as having been received since the last meeting, including, amongst others:—

Henri Andoyer, Nouvelles Tables Trigonométriques Fondamentales, tome 1, presented by the University of Paris; and Memoir on a Trans-Neptunian Planet (Lowell Observatory Memoirs, vol. i.), presented by Percival Lowell.

Note on Lines of Silicon in the Spectra of B Stars.

By A. Fowler, F.R.S.

The spectrum of silicon is of exceptional interest in consequence of the remarkable variations of the lines which accompany changes in the conditions of excitation. Lockyer has already classified the lines in four groups, in accordance with their mode of production, and has shown that each group is represented with greatest intensity in stars at different stages of development. Thus the lines of the arc spectrum, constituting Lockyer's Group I., are most strongly developed in stars approximating to the solar or G type; the spark lines of Group II. in the F and A stars; and those of Groups III. and IV. at successively higher stages of the B stars. The Group IV. lines are, in fact, practically confined to the earliest varieties of the B stars, designated B1 and Bo, and in the laboratory are only well developed when the more powerful condensed discharges are utilised.

Lockyer's investigations of the silicon spectra extended over only a small range of the spectrum, and it seemed very desirable to explore the ultra-violet and less refrangible regions for additional lines of Groups III. and IV. In this way it was hoped to obtain data for the investigation of series relationships, and especially to ascertain if the lines of Group IV., requiring the most violent excitation, gave any evidence of a change in the type of series beyond that already recognised as occurring in magnesium and the alkaline earth metals on passing from arc to spark lines.*

The new observations cover the region from λ2000 to λ7000, and many new lines, some of which are of great intensity, have been detected. The arrangement of the lines in series, however, has not yet been discovered, but the existence of equidistant pairs in Groups II. and IV., and of triplets in Group III., is strong evidence that series relationships exist. The numbers of such related lines in the region covered by the observations have not been found sufficient to reveal the characteristics of the series, and an extension of the observations into the Schumann region, or a study of Zeeman effects, may be necessary to throw further light upon the question.

Meanwhile, it may be of interest to record that at least four

* A. Fowler, *Phil. Trans.*, A, vol. ccxiv. p. 225 (1914).

additional lines occurring in stars of type B have been identified with lines belonging to the fourth group of silicon. The provisional wave-lengths of these lines, as determined in the laboratory spectrum, and the wave-lengths of the corresponding stellar lines, as given by Miss Cannon for β Crucis,* are shown in the appended table:

β Crucis (Type B1).		Silicon IV.	
Wave-length.	Intensity.	Wave-length.	Intensity.
5740·8	3	5740·2	10
4829·4	2	4829·4	4
4819·6	1	4820·1	3
4812·2	1	4813·7	2

It will be seen that the agreement in wave-lengths and relative intensities is sufficiently close to establish the identification, taking account also of the fact that other lines of the same silicon group are undoubtedly present in the stars.

Other lines of Group IV. which might be expected in the early B stars are at wave-lengths 3590·5 and 3487·1, but the stellar measurements at present available are not adequate to prove their presence. The line at 3590·5 falls very close to a helium line at 3587·4, and would perhaps not be separated from it in photographs taken with small dispersion. There are apparently no existing measurements of stellar spectra which extend as far in the ultra-violet as 3487, though observations in this region might be very valuable.

The Illumination of the Field of a Photographic Objective.
By H. C. Lord.

The uniformity of the illumination of the field of a photographic objective is a matter of great importance, and especially so in those used for astronomical purposes. So far as I am aware, no convenient formulas are available for computing the intensity of this illumination at any point in the field. The following discussion is offered as a partial solution of the problem. It is based entirely upon geometric optics, and no account is taken of the losses by reflection and absorption.

In any combination of lenses which may be used as a photographic objective there is introduced at some point in the system a stop or diaphragm at whose centre the axis of a bundle of oblique rays is compelled to cross the optic axis of the system of lenses. This real stop may be considered as the image, formed by successive refractions at the several optic surfaces, of an imaginary stop whose centre is at the intersection of the optic axis of the system

* *Ann. Harv. Coll. Obs.*, vol. xxviii., pt. ii., p. 237.

of lenses and of the axis, prolonged, of the oblique bundle of incident rays before refraction at the first surface. This point of intersection is called the entrance pupil point. Let its distance from the first optic surface be denoted by D′. It will now be shown that the intensity of illumination I at any point of the field, expressed in terms of the intensity at the centre taken as unity, may be determined as a function of D′/F where F is the focal length of the objective.

The diameter of this imaginary stop will be the effective aperture of the objective. Let us imagine a bundle of parallel rays whose axis passes through the entrance pupil point and makes an angle ϕ with the optic axis of the system; further, let the cross section of this bundle, taken perpendicular to the optic axis of the objective, be a circle of the same area as that of the imaginary stop at the entrance pupil, that is, of the same area as the rated aperture

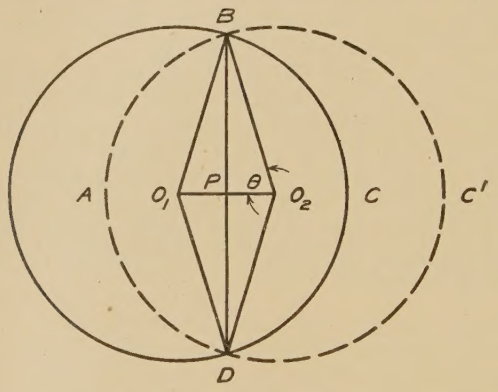

FIG. 1.

of the objective. This bundle will form an illuminated circle upon a plane tangent to the front surface of the objective at the point where the optic axis cuts it, whose centre will be at a distance of D′ tan ϕ from the centre of the front lens. In most high-class objectives the actual aperture of the front lens is the same as that of the imaginary stop at the entrance pupil point, as may be easily seen by looking through the front lens at the real stop, which will appear to fill completely the front lens itself. This case will be first discussed, leaving the case where the front lens is larger than its rated diameter until later.

The front lens, together with the above-mentioned illuminated circle, will then appear as in fig. 1, where the solid circle represents the front lens with its centre at o_1 and the broken circle represents the illuminated circle on the tangent plane with its centre at o_2. Obviously the only light which can pass through the objective to form an image of a point on the focal plane at an angular distance ϕ from the optic axis will be that which passes through the area ABCD. The intensity of the illumination at the point where

these rays come to a focus in terms of that at the centre taken as unity, will be measured by the area ABCD projected upon a plane normal to the axis of the oblique bundle of rays and divided by the area of the circle ABC′D. To find an expression for this quantity we proceed as follows: in fig. 1 we have the angles $Bo_1o_2 = Bo_2o_1 = \theta$, and, as above, $o_1o_2 = D' \tan \phi$. From these it follows that

$$\cos \theta = \frac{D' \tan \phi}{2R},$$

in which R is the semi-aperture of the objective. If then N denote the size of stop on the F system, we will have

$$\cos \theta = \frac{ND' \tan \phi}{F}.$$

The area ABo_2D will then be given by

$$ABo_2D = \frac{\pi F^2 \theta^\circ}{720^\circ N^2}.$$

The area of the triangle Bo_2D is given by

$$Bo_2D = \frac{D'^2 \tan \theta \tan^2 \phi}{4}.$$

Evidently $ABD = ABo_2D - Bo_2D$ and ABCD is twice this, whence we have

$$ABCD = 2\left[\frac{\pi F^2 \theta^\circ}{720^\circ N^2} - \frac{D'^2 \tan \theta \tan^2 \phi}{4}\right].$$

Also we have the area $ABC'D = \pi R^2 = \frac{\pi F^2}{4N^2}$; introducing these values we have for I

$$\frac{ABCD}{ABC'D} = I = \frac{2\left[\frac{\pi F^2 \theta^\circ}{720^\circ N^2} - \frac{D'^2 \tan \theta \tan^2 \phi}{4}\right]}{\frac{\pi F^2}{4N^2}} \cos \phi.$$

Introducing the value of $\cos \theta$ the above readily reduces to

$$I = \left[\frac{\theta^\circ}{90^\circ} - \frac{\sin 2\theta}{\pi}\right] \cos \phi.$$

This combined with the formula for $\cos \theta$ given above completely solves the problem, the labour of computation being very slight. Figs. 2, 3, 4, and 5 are the curves of illumination over half of the field for varying values of $\frac{D'}{F}$ for the F system of stops indicated by the values of N as shown. The abscissæ are the values of the angle ϕ and the ordinates are the intensity of illumination calculated by the above formula but expressed in per cent.

Before proceeding to investigate the case where the actual diameter of the front lens is greater than the nominal diameter of

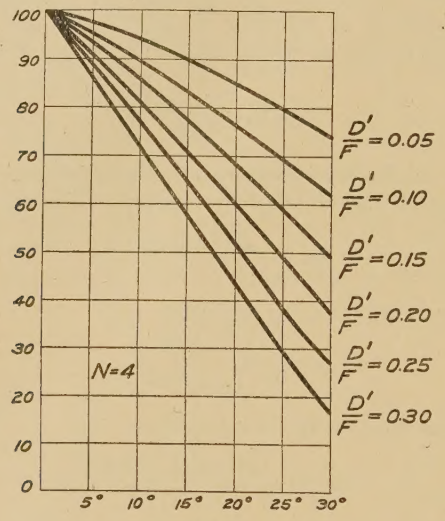

FIG. 2.

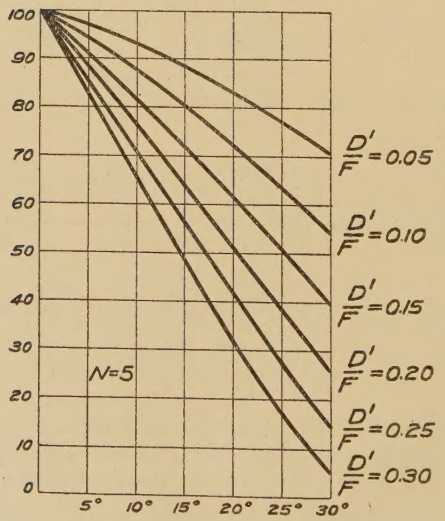

FIG. 3.

the objective, we will give the formulas for computing the values of D'. Let the distances of the first and second principal planes

of the front combination from the first and last surfaces of the front combination be denoted by C_{02} and C_{02}', and the focal length

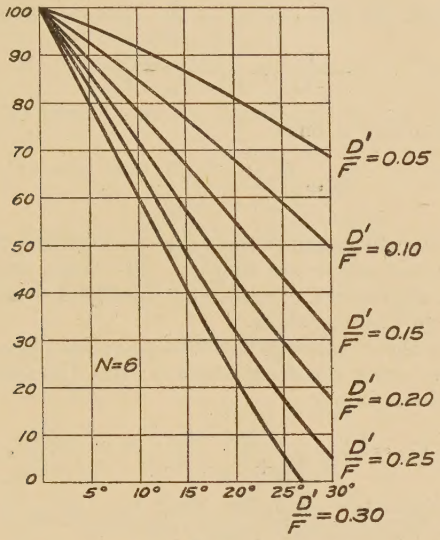

FIG. 4.

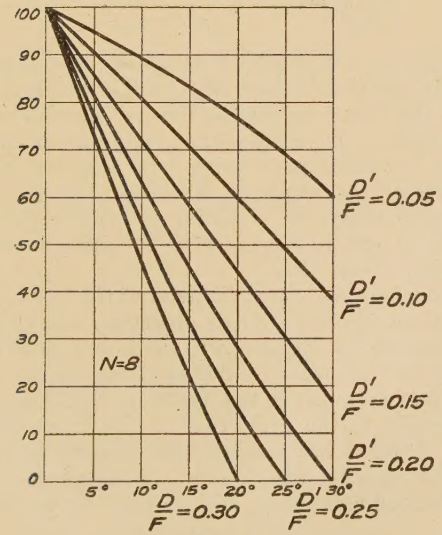

FIG. 5.

by F_{02}, and C_{46}, C_{46}', and F_{46} denote similar quantities for the back combination. We will then have $D' - C_{02}$ equal to the

distance from the first principal point to the entrance pupil point, and hence, by the theory of conjugate focii, if x be the distance of the stop from the last surface of the front combination and y its distance from the first surface of the back combination,

$$\frac{1}{x - C_{02}'} = \frac{1}{D' - C_{02}} - \frac{1}{F_{02}}.$$

From this we obtain at once

$$D' = \frac{F_{02}(x - C_{02}')}{F_{02} + x - C_{02}'} + C_{02}.$$

This may be used to compute the value of D′ when the constants of the front combination are known. In certain special cases of very general application D′ may be readily determined experimentally, as we will now show.

Let C_{06} be the distance of the first principal plane of the complete objective from the front surface; the Gaussian theory of thick lenses then gives

$$C_{06} = C_{02} + \frac{F_{02}(x - y - C_{02}' + C_{46})}{F_{02} + F_{46} + x - y - C_{02}' + C_{46}}.$$

If we now impose the conditions that $F_{46} = mF_{02}$, $C_{46} = -mC_{02}'$, and $y = -mx$, the above will readily reduce to

$$C_{06} = C_{02} + \frac{F_{02}(x - C_{02}')}{F_{02} + x - C_{02}'}.$$

The above expression is exactly the same as that found above for D′; hence it follows that in those objectives in which the simple lens equivalent to the back combination has its Gaussian constants proportional to those of the simple lens equivalent to the front combination, that the first pupil point will coincide with the first principal plane of the complete objective. If the ratio m has the special value unity, the objective is evidently a symmetrical doublet, provided each half consists of the same number of lenses built out of similar material.

In the case where the actual diameter of the front lens is greater than the effective diameter of the objective, or, in other words, where the objective is stopped down, the intensity of the illumination will vary as the cosine of the angle ϕ until the illuminated circle on the plane tangent to the vertex of the front lens becomes tangent internally to the projection of the front lens upon the same plane. After ϕ has reached this limiting value, which we will call ϕ_0, the intensity will follow a more complex law. It is easily seen that the value of ϕ_0 will be given by the equation

$$\tan \phi_0 = \frac{2NR - F}{2ND'}$$

where R equals the semi-aperture of the first lens.

In fig. 6, let the larger circle be the front lens and the smaller one the illuminated circle upon the plane tangent to the vertex of the first surface, ϕ being greater than ϕ_0. It is then evident that

$$r \sin \theta_2 = R \sin \theta_1$$
$$r \cos \theta_2 = R \cos \theta_1 - D' \tan \phi.$$

Eliminate $\cos \theta_2$ from these two equations, replace r by $\frac{F}{2N}$ and R by $\frac{kF}{2N}$, and we will have

$$\cos \theta_1 = \frac{F(k^2 - 1)}{4kND' \tan \phi} + \frac{ND' \tan \phi}{kF}.$$

If in the above expression R is made equal to r, or, in other words,

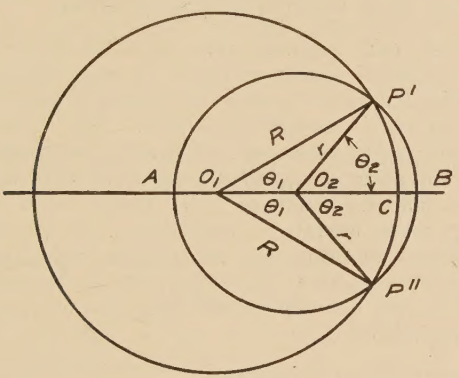

Fig. 6.

k is put equal to unity and the resulting value of θ_1 is called θ_0, we will have

$$\cos \theta_0 = \frac{ND' \tan \phi}{F}$$

and the equation for θ_1 becomes

$$\cos \theta_1 = \frac{F(k^2 - 1)}{4kND' \tan \phi} + \frac{\cos \theta_0}{k}.$$

From these it may readily be shown that

$$\cos \theta_2 = k \cos \theta_1 - 2 \cos \theta_0.$$

The intensity of the illumination at any point ϕ will then be given by

$$I = \frac{\text{area } P'AP''C}{\text{area } P'AP''B} \cos \phi.$$

From the figure it is evident that

$$P'AP''C = P'o_1P''C - P'o_1P''o_2 + P'AP''o_2$$

$$P'o_1P''C = \frac{\pi R^2\theta_1}{180^\circ}$$

$$P'o_1P''o_2 = rR \sin(\theta_2 - \theta_1)$$

$$P'AP''o_2 = \frac{\pi r^2(180^\circ - \theta_2)}{180^\circ}.$$

From the above it easily follows that

$$I = \left[1 + \frac{k^2\theta_1 - \theta_2}{180^\circ} - \frac{k \sin(\theta_2 - \theta_1)}{\pi}\right] \cos\phi.$$

This equation serves to compute the value of I when ϕ is greater that ϕ_0, so that the problem is completely solved.

[*Note added* 1916 *January* 18.—Since the above was in type it has been suggested that there might be some misunderstanding as to its application to the relative intensities of the star images at different parts of a photographic plate. The formulas derived enable one to compute this loss in intensity, neglecting the effect of reflection and absorption, *just as long as the star images remain perfect.* But any distortion of these images such as would be produced by coma, curvature, astigmatism, or distortion of the diffraction pattern would cause a still greater loss. These formulas give the maximum relative intensities that can be secured. They can be applied over a much greater field, however, when applied to a luminous surface.]

The Emerson McMillin Observatory,
The Ohio State University,
Columbus, Ohio, U.S.A.:
1915 *October* 1.

Preliminary Paper on Recent Lists of New Double Stars.

By Eric Doolittle.

For several years past we have been engaged at this observatory in forming an extension of Burnham's *General Catalogue of Double Stars*, adding all measures made since the work was published and also all pairs since discovered. The first part of this programme is as yet only about two-thirds completed to date; the second part, except for occasional scattered pairs, is, however, practically complete.

In the MS. Catalogue there are thus far included 2900 pairs of Aitken, 1516 of Hussey, 1405 of Espin, 1034 of Jonckheere, and many hundreds from shorter lists, as well as some one or two

hundred noted as double in the catalogues of the Astronomische Gesellschaft Zones,—about 8000 pairs altogether. The first step with each pair is to identify it, when possible, in a star catalogue, and the position is next reduced to the standard epoch 1880·0. It is errors found in the course of this work that are mentioned in the present paper. But few references are here made to pairs already included in the G.C.; there are also some one hundred pairs among the new stars (and many more among the old ones) wherein apparent discrepancies can only be cleared away at the telescope. These will form the basis of one or more future papers.

The original announcement of the following new pairs will be found in the following references. Some of the errors noticed have been already published, but for completeness they are nevertheless included.

Aitken Pairs.—In the *L.O. Bulletins*, Nos. 109 to 263.

Espin Pairs.—In the *M.N.*, vols. lxv. to lxxv.

Jonckheere Pairs.—In the *Journal Astronomique*, vols. i. and ii., and also in *M.N.*, vols. lxxi. and lxxii., and in *A.N.*, 4406, 4461, 4484, and 4510.

Hussey Pairs.—*L.O. Bulletin*, 117, and *Pub. Detroit Obsy.*, vol. i.

E. D. Roe Pairs.—*Popular Astronomy*, Nos. 176 and 179; *A.J.*, No. 611; and *A.N.*, Nos. 4338, 4381, 4467, 4510, 4544, and 4762.

Errors and Coincidences in Recent Lists of Stars.

Aitken Pairs.

A 1262. In A.G. Bonn, 19″·91 should be 18″·91. Aitken's Decl. is, however, correct.
1269. The R.A. is 30 s. too large in *L.O.B.* 109.
1310–1311. The measures and magnitudes ascribed to these two pairs should be interchanged (see *L.O.B.*, vol. v.).
1345. This is the star A.G. Vienna 3853, not 3855.
1349. Measured on two nights.
1364. This is Espin 311.
1367. The R.A. is 1 min. too great in *L.O.B.* 109.
1408. +57° (3685) should be +37° (3685).
1465. The R.A. is 20 s. too small in *L.O.B.* 109.
1492. It is the position of the DM star that is here given. The DM magnitude is 8·4.
1532. The R.A. is 10 s. too large in *L.O.B.* 125.
1686. The pair is Hels.-Gotha 11796.
1801. Decl. is 30′ too small in *L.O.B.* 144; the error also occurs in A.G. Leip. ii. This pair is DM +7° (10).
1874. For Σ31′ read Σ32, App. I.
1891. +13° (5140) should be −13° (5140).
1919. The pair is A.G. Nic. 383.
2040. This had been previously measured by Burnham. . . . (4353).

2062. The R.A. is 41 s. too great in *L.O.B.* 171.
2111. Measured by Barnard in 1899, but this measure is not yet published.
2141. Also listed as Espin 1245.
2148. $+23^{\circ}$ (2208) should be $+23^{\circ}$ (2204) in *L.O.B.* 184.
2239. The Decl. is 2′ too small in *L.O.B.* 188.
2241. The R.A. is 10 s. too small in *L.O.B.* 188.
2265. -21° (2267) should be -21° (2257).
2301. Also listed as J 219.
2303. Also listed as J 585.
2359. AC was measured on two nights.
2364. The R.A. is 5 s. too small in *L.O.B.* 204.
2437. The Decl. is 1° too large in *L.O.B.* 223.
2444. The R.A. is 10 s. too small in *L.O.B.* 223.
2497. This pair is A.G. Bonn 16555.
2523. The R.A. is 20 s. too small in *L.O.B.* 245.
2526. The published angle of AB is 180° too large.
2542. The R.A. is 20 s. too great in *L.O.B.* 240: also listed as Espin 425.
2567. This is also listed as J 1010: his distance is, however, considerably too small.
2576, CD. Listed as J 428.
2649. This is J 676.
2659. The R.A. is 6 s. too small in *L.O.B.* 251.
2678. This is J 666.
2815. This is J 690.
2852. This is J 705.

L.O.B. 184, p. 62, line 4: for A 2196 read A 2197. *L.O.B.* 251, line 4: A 2659 should be A 2655.

L.O.B. 125. A.G. Har. 930 = AC of Aitken 1921.

Espin Pairs.

Es. 42. The note "See p. 1055" on page 267 of the G.C. belongs to Es. 115. Similarly, on page 1055, 167 should be 166. This pair was again announced as new (= Es. 154). The G.C. place is slightly in error.

154. This is Es. 42.
190. Discovered and measured by Tarrant, = G.C. 8873.
199. Espin's angle is 100° in error.
195. Also called Hussey 946.
205. $+34^{\circ}$ (3936) should be $+34^{\circ}$ (3937). Rediscovered by J, (= J 128).
208. Called Hussey 1311.
249. Not $+33^{\circ}$ (4031). It is 25·4 s. pr. and 1′·4 n. of $+33^{\circ}$ (4028).
252. Called Hussey 1309.
278. This is Σ 3114.
352. Called also Hussey 1301.
380. In note, BC should be CD.

405. The position given agrees with that of +57° (170); not +57° (171).
411. Called Hussey 1217.
427. This is Aitken 553.
437. This is β 1324.
646. Espin's Decl. is 3′ too small.
— +44° (3569), 20 h. 41 m. 48 s. The R.A. is 1 min. too small.
699. The Decl. is 10′ too small.
701. The Decl. is 10′ too large.
720. The Decl. is 5′ too small.
733. Incorrectly identified. Probably +54° (1589).
742. There is no DM star in this place, but +54° (1769) is near.
771. The Decl. is 10′ too small.
773. Called +50° (2115) by Espin, and this is probably correct, but the place given is that of +50° (2112).
774. The R.A. is 30 s. too small and the Decl. 10′ too large. No DM star in Espin's place.
775. The Decl. is 5′ too large.
776. The Decl. is 30′ too small.
865. +51° (330) should be +51° (33).
903. The R.A. is 2 min. too small.
921. The Decl. is 6′ too large.
941. The R.A. is 2 min. too small. This is very probably H 2008.
944. The Decl. is 7′ too large.
965. +52° (1828) should be +53° (1828).
973. The R.A. is 1 min. too small.
988. +51° (2550) should be +51° (2850).
996. The Decl. is 32′ too large.
1006. The Decl. of the DM star is +51° 56′1. No star in Espin's place.
1007. The R.A. is 1 min. too great.
1069. The R.A. is 2 min. too small.
1070. The R.A. is 1·5 min. too small.
1078. Probably identical with H 2354 with an error in one of the angles. The places agree.
1087. The R.A. is 3 min. too small.
1125. The R.A. is 2 min. too small.
1131. Called J 876.
1135. +49° (768) should be +48° (768).
1147. This is H 1164, but C was not referred to by H. Both components were measured by Espin in 1900. (See the G.C.)
1178. +48° (2638) should be +48° (3638).
1185. +49° (4010) should be +49° (4020).
1186. Identical with Espin 694.
1215. The Decl. is 7′ too small.
1221. +49° (1009) should be +49° (1019).
1241. The Decl. is 10′ too small.

1245. This is also Aitken 2141.
1259. +46° (2581) should be +46° (2381).
1267. The Decl. is 3′ too small.
1309a. (*κ Persei.*) The Decl. is 30′ too large.
1310. If Espin's identification is correct, the Decl. is 45′ too small.
1327. The Decl. is 3′ too large.
1347. The Decl. is 21′ too small.
1354. The identification and position are the same as of J 863, but the descriptions disagree.
1375. This is J 897.
1385. The angles by Espin and J differ by 26°·4.

Jonckheere Pairs.

(For corrections J 1–J 130 see *Astronomical Journal*, No. 679.)

J94. This is double in A.G. Leip. Measured by Lp. in 1893, and by Cog. in 1903.
132. The R.A. is 1 hr. too small. This is β 659.
135. Afterward registered as J 175, but there is an error in one of the positions.
136. R.A. is 1 hr. too small.
139. Measured by β in 1904, and hence not new. (See G.C. 9484*a*).
151. Magnitudes disagree in J.A. 1, p. 86, and (4461).
152. R.A. 2 min. too large. Magnitudes disagree in the two references cited.
154. The second magnitudes differ in the two published lists.
156. The magnitudes differ.
167. The magnitudes differ. Roe measures the position of this pair as 6·1 s. following and 8″·3 south of +1° (4760). This makes J's R.A. 1 min. and his Decl. 2′ in error.
175. Identical with J 135 very probably.
176. The R.A. is 1 hr. too great. This pair is J 549.
180. For A.G. Leip. i. read A. G. Leip. ii.
189. The Decl. is 5′ too small.
211. Identified with +23° (4668), but the position given is that of +23° (4669)
219. Also registered as Aitken 2301.
227. The Decl. is 10′ too small.
274. The identification should be +8° (1560).
289. The dates disagree in the two published lists.
291. The Decl. is 7′ too small.
304. The two published magnitudes disagree.
307. The mean of the two nights in error in (4484).
309. The magnitudes differ in the two published lists.
311. The published distances differ.
357. This is Aitken 516, but A's identification is in error.
378. +4° 27′ should be −4° 27′.
407. The published magnitudes of B differ.

408. $+9^{\circ}$ (117) should be $+9^{\circ}$ (1174) in J.A. This is β 96, CD.
428. This is Aitken 2576, CD.
436. $+0^{\circ}$ (3161) should be $+0^{\circ}$ (3061).
477. This is A.G. Leip. 7008. Measured by Lp. and Miller.
483. The printed distance should be $2''{\cdot}23$.
549. This is J 176.
551. Apparently this is the star B of G.C. 10007 1/2.
563. This is Roe 14, BC.
580. The Decl. is $6'$ too large.
585. Also called Aitken 2303.
604. The Decl. is $6'{\cdot}5$ too small.
607. The identification should be $+17^{\circ}$ (4467).
666. Also = Aitken 2678.
670. The identification should be A.G. Leip. ii. 11556.
676. Also = Aitken 2649.
690. Also called Aitken 2815.
745. $+7^{\circ}$ should be -7° in J.A.
705. Also called Aitken 2852.
774. This may be identical with J 541.
810. This is the component CD in the quadruple group A.G. Leip. 6922. Measured by Cog. in 1904, but the magnitudes of J and Cog. differ remarkably.
863. Identification and position the same as of Espin 1354, but the descriptions disagree.
876. Later catalogued as Espin 1131.
897. Later called Espin 1375.
915. Called $+14^{\circ}$ (4675), but the place is that of $+14^{\circ}$ (4678).
917. This is probably β 844, though the R.A.'s differ by 5 s. and the Decl.'s by $2'$. The descriptions agree.
948. The star is $+14^{\circ}$ (1048), 6·8 magnitude. If the note regarding this is correct, J's R.A. is 2 min. too great.
982. In J.A. 2, p. 11, for the second J read D.
997. For the second J read D.
1000. The R.A. is 1 min. too great.
1010. This is also Aitken 2567.
1012. This is Σ1518 *rej.* BC.
1022. The third date should be 1913·324 in J.A. 2, p. 16.
1023. The R.A. is 1 min. 13 s. too small. The place given agrees with that of $+37^{\circ}$ (2286).

Hussey Pairs.

1201. This is a closer component to A of Hough 490.
1217. Published also by Espin, = Es. 411.
1222. The identification should be $+14^{\circ}$ (833),
1230. The R.A. is 2 min. too small.
1277. The R.A. is 19 s. too small.
1301. Afterward published as Espin 352.
1309. Also called Espin 252.
1311. This is Espin 208.

1399. Identical with H 3823, but the description seems in error.
1503. R.A. is 44 min. too large.
1524. For Decl. 36′·7 read 37′·6.

E. D. Roe Pairs.

23. The R.A. is 2 min. too small.
24. The R.A. is 2 min. too small.
33. +11° (2037) should be +7° (2037).
46. This is Espin 261.
51. This is β 51.
55. The R.A. is 4 min. 23 s. too small and the Decl. 24′ too great.
59. The Decl. is 10′ too small.
78. This is β 442, *Aa*.
79. This is A.G. Leip. (see A.G. Leip., i. p. 211). Measured by Lp. and Miller.
81. The Decl. is 4′ too large.

University of Pennsylvania :
1915 *November* 20.

New Double Stars. By the Rev. T. E. Espin, M.A.

No.	B.D.	R.A. 1900. h	m	Decl °	′	P. °	D. ″	Mags.		Nts.	Date. 1915.	
1406	+43° 12	0	6·0	+43	46	349·4	4·87	9·2	14·0	3	·983	
						332·8	9·63	A	8·5	3	·983	
1407	+44° 52		11·6	44	21	221·4	2·31	9·5	11·5	2	·885	
1408	+43° 137		37·5	43	22	260·4	7·64	9·2	9·3	3	·940	
1409	+43° 266	1	13·2	43	59	216·0	4·69	9·6	12·0	2	·888	
1410	+43° 298		21·4	43	43	124·3	4·11	11·3	13·9	3	·940	BC
						89·1	20·34	A=	9·5	2	·917	AB
1411			45·1	44	34	236·6	1·65	9·5	9·7	3	·903	
1412	+44° 2666	17	7·9	44	4	132·4	3·64	9·6	9·7	3	·677	
1413	+43° 2728		21·5	43	32	248·6	6·51	9·5	11·0	2	·691	
1414	+43° 2741		26·8	43	39	232·8	7·14	9·3	9·7	2	·691	
	+43° 2837		50·5	43	14	333·7	9·89	9·3	9·6	3	·700	
1415	+43° 2844		52·9	43	52	120·5	2·27	9·5	12·9	4	·675	
1416	+44° 2813	18	0·1	44	42	72·1	1·61	9·5	9·7	4	·615	
1417	+43° 2898		6·1	43	12	276·1	3·24	9·8	13·8	4	·747	BC
						234·6	7·32	A=	8·9	3	·731	AB
1418	+43° 2902		6·4	43	18	308·3	3·62	9·2	13·1	2	·738	
1419	+43° 2911		9·0	43	53	274·3	4·87	9·4	10·5	3	·643	

No.	B.D.	R.A. 1900. h	m	Decl. °	′	P. °	D. ″	Mags.		Nts.	Date. 1915.	
1420	+44° 2861	18	12·6	+44	15	68·1	8·58	8·9	10·1	3	·617	AB
						6·7	19·60	C=	13·2	3	·617	AC
1421	+44° 2863		13·3	44	21	348·1	9·45	8·5	11·7	3	·617	
1422	+43° 3020		32·2	43	9	81·2	4·35	9·5	10·2	3	·740	
1423	+43° 3045		38·1	43	50	333·6	6·95	9·1	9·5	3	·662	
1424	+44° 2986		42·0	44	15	90·6	8·85	7·9	13·0	2	·643	
1425	+42° 3158		43·6	42	56	231·3	4·53	9·0	9·1	2	·781	
1426	+43° 3099		48·1	43	17	252·4	6·60	8·7	14·0	2	·721	
1427			49·0	43	16	109·7	4·04	9·5	12·7	3	·739	
1428	+43° 3119		52·5	44	3	132·7	2·97	13·5	13·7	3	·654	BC
						96·0	24·54	A=	8·7	3	·654	AB
1429	+43° 3140		57·4	43	5	7·6	5·25	8·8	9·8	3	·730	
1430			59·2	42	21	102·7	1·41	9·5	11·0	2	·820	
1431	+44° 3072	19	6·9	44	12	58·7	7·07	9·4	13·4	3	·604	
1432	+43° 3236		22·0	43	28	267·7	4·12	13·1	13·5	2	·721	BC
						175·5	31·00	A=	8·7	2	·721	AB
1433	+43° 3239		22·4	44	1	194·3	1·82	9·2	10·5	4	·674	
1434	+43° 3296		32·6	43	7	212·9	3·16	9·5	10·6	3	·694	
1435	+43° 3330		39·1	43	59	120·8	5·39	9·5	13·3	4	·657	
1436	+43° 3435		55·3	43	25	180·4	2·99	9·5	10·9	2	·685	
1437	+42° 3575	20	0·6	43	4	267·3	4·15	9·5	12·0	3	·859	
1438	+43° 3509		6·0	43	35	41·9	5·79	8·4	13·5	3	·676	
1439			13·0	43	20	24·8	1·54	9·6	9·8	2	·779	
1440	+42° 3676		14·5	43	0	260·0	2·60	9·2	10·2	2	·842	
1441	+44° 3492		26·9	44	19	127·9	2·22	9·2	9·4	2	·669	
1442	+44° 3493		27·1	44	15	265·6	2·30	9·5	13·2	2	·669	
1443	+43° 3634		28·0	43	43	290·6	2·73	9·1	10·7	2	·750	
1444	+43° 3661		31·3	43	13	80·7	5·26	9·5	12·7	2	·784	
1445	+43° 3687		38·1	43	29	177·3	6·09	9·0	10·6	2	·686	
1446	+42° 3839		39·4	42	49	130·9	4·46	8·8	11·6	2	·853	
1447	+42° 3846		40 2	42	55	309·6	2·27	9·2	10·5	2	·842	
1448	+43° 3703		41·3	43	10	137·5	2·24	9·1	9·5	4	·732	
1449	+43° 3706		41·7	43	16	57·4	6·84	8·7	9·2	2	·721	
1450	+42° 3919		53·7	42	55	160·3	4·67	8·5	12·5	2	·944	
1451	+42° 3925		54·8	43	4	111·1	8·61	9·3	10·5	2	·738	
1452	+42° 3978	21	3·5	42	58	17·4	1·96	9·1	10·5	2	·747	
1453	+42° 3988		6·3	43	2	67·6	5·65	8·5	8·8	2	·712	
1454			7·1	43	21	284·8	2·88	10·0	10·0	2	·686	
1455	+42° 4131		29·4	42	39	291·2	5·82	9·5	14·0	2	·740	
1456	+42° 4147		31·8	42	35	135·3	4·27	9·5	12·0	3	·755	

No.	B.D.	R.A. 1900.	Decl.	P.	D.	Mags.	Nts.	Date. 1915.	
		h m	° ′	°	″				
1457	+41° 4204	21 32·1	+41 11	77·9	3·64	9·4 12·7	2	·932	
1458	+42° 4163	34·2	42 31	190·7	5·11	8·7 12·8	3	·835	
1459		41·4	42 31	279·9	1·96	9·8 9·8	3	·889	
1460	+41° 4263	42·3	42 11	2·0	1·80	9·3 11·0	3	·941	
1461	+42° 4242	49·9	42 29	355·2	5·87	9·5 13·5	3	·754	
1462	+42° 4291	22 0·8	42 48	181·7	1·52	9·1 9·3	3	·740	BC
				15·0	43·11	A= 9·1	2	·733	AB
1463	+41° 4412	7·2	41 55	245·2	6·46	9·5 13·3	4	·907	BC
				194·1	34·42	A= 9·3	2	·898	AB
1464	+42° 4323	8·2	42 52	149·7	1·39	9·4 9·8	3	·777	
1465	+42° 4356	15·8	42 35	116·4	4·82	9·5 13·9	2	·783	
1466	+42° 4360	17·0	42 38	260·2	6·11	9·3 13·2	3	·804	
1467	+43° 4208	23·8	43 36	228·2	7·94	6·5 13·7	3	·675	
1468	+42° 4445	29·9	43 10	329·4	5·88	8·7 9·0	2	·735	
1469	+42° 4449	31·3	42 36	39·9	6·52	8·5 11·6	3	·777	
1470	+42° 4459	33·0	42 52	335·1	5·45	9·4 9·7	2	·783	
1471	+43° 4275	38·0	43 16	91·6	3·60	8·7 13·8	2	·684	
1472	+43° 4328	48·3	43 40	36·1	2·39	9·3 11·1	2	·782	
1473	+42° 4704	23 28·9	42 52	136·7	1·45	9·4 9·5	3	·831	
1474	+42° 4723	33·6	42 55	92·9	7·53	9·3 9·4	2	·857	
1475	+42° 4760	42·2	43 0	303·2	5·28	8·5 9·1	3	·790	
1476	+42° 4779	46·8	42 31	59·1	1·42	9·6 9·7	3	·891	AB
				245·4	15·22	C= 12·5	2	·885	AC
1477	+41° 4885	47·5	42 14	346·3	4·49	9·5 13·2	2	·917	
1478	+43° 4587	52·8	43 31	2·2	1·33	9·5 10·4	2	·762	
1479	+42° 4797	52·9	43 12	104·5	3·50	9·5 9·6	2	·872	

Notes.

1419. This star is 1′ too far N. in Argelander.
1426. This pair is P, and 1427 is F β421.
1429. Star, 14·5, at 75°·8 ± 9″ from B.
1432. Star, 13·5, at 293°·7, 26″·9.
1444. Star, 13·0, at 97°·8, 14″·6.
1450. Star, 10·0, at 317°·3, 26″.
1454. Forms a distant *comes* to B.D. + 43°, 3830, at P 114°.
1460. Star, 14·0, at 235°·8, 20″.
1462. Star, 13·8, at 317°·1 makes a triangle.

The R – D Discordance of the Greenwich Transit Circle.

(*Communicated by the Astronomer Royal.*)

During the year 1915 a modification has been made in the reflection observations taken with the Greenwich Transit Circle. They have been made singly and not in conjunction with the observations made directly. The advantages of this procedure are that there is no hurry in the observations, and that they are made symmetrically about the meridian.

The method of adopting the zenith point is necessarily somewhat different. It has been the practice at Greenwich to determine this by a combination of nadir observations with reflection observations taken north and south of the zenith. This year the zenith point has been derived from the nadir observations alone in the preliminary reductions.

The observations are then compared with Boss's Preliminary General Catalogue, and values B – R and B – D found for different zenith distances. By subtraction R – D is found, which is independent of Boss's positions.

Owing to the war the observations are not so numerous as they would otherwise have been, but they are sufficient to exhibit some interesting results. A summary of the observations is given in the following table:—

Zenith Distance.	Number of Observations.		Boss – R.	Boss – D.
	R.	D.		
−63° 40′	12	11	−0″·39	−0″·52
−53 0	11	11	−0·46	−0·52
−41 15	14	16	−0·93	−0·31
−31 52	11	12	−0·63	0·00
−21 41	10	12	−0·68	−0·07
+22 47	16	28	+0·21	+0·42
+32 18	16	21	+0·32	+0·57
+40 27	10	13	−0·22	+0·66
+51 20	17	23	−0·13	+0·90
+62 57	16	26	−0·44	+0·89
Mean			−0·34	+0·20

As these groups are distributed symmetrically about the zenith, the means 0″·34 and 0″·20 are the corrections to the zenith point as derived from nadir observations. The mean of these 0″·27 is independent of Boss's positions, and agrees sufficiently well with results of recent years for the correction of the nadir observation from north and south reflections.

Taking out this constant, and writing the observations in a

different order so as to bring corresponding zenith distances north and south side by side, we find

Z. D.	Boss – R.		Boss – D.	
	North.	South.	North.	South.
°	″	″	″	″
22	– ·41	+ ·48	– ·34	+ ·15
32	– ·36	+ ·59	– ·27	+ ·30
41	– ·66	+ ·05	– ·58	+ ·39
52	– ·19	+ ·14	– ·79	+ ·63
63	– ·12	– ·17	– ·81	+ ·62

The D observations are satisfactorily represented by the formula + ·75″ sin z. It is quite clear that a sine formula will not represent the R observations. The discordances in the R – D from a sine formula are apparently all attributable to the reflection observations. There appears to be a symmetry about the observations which makes them available for zenith point, though this point requires more observations.

These anomalies in the reflection observations may possibly be attributed to some refraction effect owing to the heating of the air by the presence of the observer and the lights in the pit of the transit circle. This is, however, merely a surmise, but it is clear that from some cause or other there is an increasing discordance with diminishing zenith distance between the limits 63° and 22°.

Royal Observatory, Greenwich:
1915 *December* 24.

The Greenwich Catalogues of Fundamental and Zone Stars for 1910.

(*Communicated by the Astronomer Royal.*)

As, owing to the exigencies of the war, the publication of these Catalogues will be somewhat delayed, it seems desirable to give the results of the observations made at Greenwich during the years 1906–1914 so far as they are of general interest to astronomers.

The adoption of Newcomb's Equinox in the 1900 Catalogue left a residual correction from the Greenwich Sun observations for the years 1897–1905 of – ˢ·014. The correction from similar observations similarly reduced for the years 1906–1914 is – ˢ·046. The discordance between the two results is considerable, and no

reason can be assigned for it. The latter correction is supported by the results of the Cape observations of the Sun, Mercury, and Venus for the years 1907–1911 with the New Transit Circle (*Annals of the Cape Observatory*, vol. viii., pt. iv., p. 38D), which are as follows:—

	s
Sun	−·064
Mercury	−·048
Venus	−·037
Mean	−·050

In connection with comparisons of the Fundamental Catalogues, the points of interest are the periodic changes in R.A. and the difference in the equator point between Newcomb and Boss.* In the following comparisons clock stars only have been used.

With reference to periodic changes in R.A., if we assume that the differences between Greenwich 1910 and the Fundamental Catalogues taken as Greenwich − Boss or Newcomb can be represented by the formula

$$A \cos \alpha + B \sin \alpha + C \cos 2\alpha + D \sin 2\alpha,$$

then for the epoch 1910 we get

Greenwich − Newcomb.

$$+^{s}\cdot0007 \cos \alpha - {}^{s}\cdot0125 \sin \alpha + {}^{s}\cdot0065 \cos 2\alpha + {}^{s}\cdot0008 \sin 2\alpha.$$

Greenwich − Boss.

$$+^{s}\cdot0030 \cos \alpha - {}^{s}\cdot0095 \sin \alpha + {}^{s}\cdot0040 \cos 2\alpha + {}^{s}\cdot0010 \sin 2\alpha.$$

If we arrange the comparison with Boss in order of magnitude, we obtain the following corrections to the Greenwich Standard Mean Right Ascensions for 1910·0 for magnitude corrections:—

$0^{m}\cdot0$–$0^{m}\cdot9$	$1^{m}\cdot0$–$1^{m}\cdot9$	$2^{m}\cdot0$–$2^{m}\cdot9$	$3^{m}\cdot0$–$3^{m}\cdot9$	$4^{m}\cdot0$–$4^{m}\cdot9$	$5^{m}\cdot0$–$5^{m}\cdot9$	$6^{m}\cdot0$–$6^{m}\cdot9$
$+^{s}\cdot013_{5}$	$+^{s}\cdot010_{11}$	$+^{s}\cdot002_{55}$	$+^{s}\cdot001$	$-^{s}\cdot004_{63}$	$-^{s}\cdot014_{27}$	$-^{s}\cdot021_{8}$

Applying these corrections to the differences Greenwich − Boss, we get

Greenwich − Boss.

$$+^{s}\cdot0023 \cos \alpha - {}^{s}\cdot0090 \sin \alpha + {}^{s}\cdot0063 \cos 2\alpha + {}^{s}\cdot0010 \sin 2\alpha.$$

The correction for magnitude equation is thus seen to affect principally the cos 2α term.

For a general reference to discussions on this subject, reference should be made to *R.A.S., M.N.*, lxxv. 4, p. 335.

With regard to declinations, the Greenwich observations for 1910·0 have been reduced with Pulkovo refractions, and the value of the colatitude 21″·80 and a flexure of +0″·6 the same as the value used in the 1900 Catalogue. The observations for 1900·0 and

* Boss's Preliminary Catalogue of 6188 stars for 1900.

1890·0 have been also corrected for reduction to Pulkovo refractions and colatitude 21″·80, and the resulting comparisons with Newcomb and Boss are given for every 10° of Dec. for the three periods 1890, 1900, and 1910.

Limits of Dec.	No. of Stars.	Newcomb.				Boss.			
		1890.	1900.	1910.	Mean.	1890.	1900.	1910.	Mean.
		″	″	″	″	″	″	″	″
+40° to +30°	9	−·12	−·13	+·05	−·07	+·07	+·22	+·39	+·23
+30 to +20	37	−·04	−·05	+·12	+·01	+·19	+·19	+·40	+·26
+20 to +10	40	−·01	−·01	+·14	+·04	+·22	+·22	+·42	+·29
+10 to + 0	36	−·08	−·28	+·01	−·12	+·21	·00	+·33	+·18
− 0 to −10	35	−·05	−·17	+·07	−·05	+·24	+·15	+·40	+·26
−10 to −20	28	−·07	−·02	+·25	+·05	+·20	+·25	+·53	+·23
−20 to −30	15	−·06	+·13	+·31	+·13	+·04	+·23	+·42	+·23
Mean	...	−·05	−·10	+·12	−·01	+·19	+·16	+·40	+·25

The results for 1910, as in the case of those for 1900, seem to require a larger flexure correction than that given by $\frac{1}{2}(R - 1)$. The mean of the thirty years' observations at Greenwich thus reduced agrees with Newcomb's equator and not with that of Boss.

In the Zone Catalogue, which extends from Dec. +24° to +32°, there are 360 stars to be found in Boss's Catalogue, which are arranged in groups of 6^h of R.A. For the declinations these stars have been subdivided into two parts: those when the Boss epoch of observation occurs before 1870 and those when it occurs after 1870. The results show for the zone between 18^h and 0^h considerable discordances, which would imply that the systematic corrections applied to the original Catalogues have not been wholly successful in bringing them into line.

Limits of R.A.	Greenwich − Boss.				Boss, Dec. after − before 1870.
	R.A.	Dec.	Boss. Dec. after 1870.	Boss. Dec. before 1870.	
h h	s	″	″	″	″
0– 6	$-·007_{89}$	$+·50_{89}$	$+·54_{44}$	$+·47_{45}$	+·07
6–12	$·000_{94}$	$+·38_{94}$	$+·39_{46}$	$+·37_{48}$	+·02
12–18	$+·004_{82}$	$+·54_{82}$	$+·52_{47}$	$+·57_{35}$	−·05
18– 0	$+·010_{95}$	$+·60_{95}$	$+·46_{57}$	$+·78_{38}$	−·32

Observations of Occultations of Stars by the Moon, and of the Star Lalande 45880 *by Jupiter, made at the Royal Observatory, Greenwich, in the year* 1915.

(*Communicated by the Astronomer Royal.*)

Day. 1915.	Phenomenon.	Mag.	Telescope.	G.M.T. h m s	Observer.
Feb. 21	Disapp. 18 Tauri	5·6	Sheepshanks	7 4 37·97	G. B.
24	,, B.D. +27° 1122	7·0	Astrographic	7 35 47·07	W. S.
24	,, ,,	,,	Sheepshanks	7 35 46·84	G. B.
Mar. 26	,, B.A.C. 2991	6·1	,,	8 6 56·17	G. B.
Apr. 23	,, B.D. +15° 2027	6·5	,,	8 13 21·88	G. B.
May 24	,, Piazzi XII. 63	7·1	,,	9 33 45·82	G. B.
June 18	,, Lalande 20357	7·4	Detached Tel. (Altaz.)	9 22 24·63	A. C.
18	,, ,,	,,	Astrographic	9 22 23·18	W. S.
21	,, W.B. XII. 793	6·0	Sheepshanks	8 42 8·29	G. B.
21	,, B.D. −11° 3398	6·7	,,	10 27 59·31	G. B.
July 28	,, 67 Aquarii *	6·3	Astrographic	14 0 55·44	F. J.
Aug. 18	,, Lacaille 6719	6·9	,,	7 45 26·67	W.
Sept. 19	,, Rumker 8872	6·0	Sheepshanks	11 5 34·05	G. B.
Oct. 28	Reapp. Lalande 45880	8·0	Astrographic	6 31 56·90	H.
	The last occultation was by Jupiter. Time uncertain ; clouds passing.				
Dec. 18	Disapp. 16 Tauri	5·4	Astrographic	11 52 26·64	H.
18	,, 19 Tauri	4·4	,,	12 8 38·59	H.
18	,, 20 Tauri	4·0	,,	12 29 8·35	H.
18	,, ,,	,,	Detached Tel. (Altaz.)	12 29 8·76	A. C.
18	,, 21 Tauri	5·9	Astrographic	12 39 13·42	H.
18	,, 22 Tauri	6·5	,,	12 41 21·87	H.
18	,, ,,	,,	Detached Tel. (Altaz.)	12 41 24·16	A. C.
18	,, B.D. +24° 562	7·0	Astrographic	13 12 18·12	H.
18	Reapp. 19 Tauri *	4·4	,,	13 23 57·43	H.
18	Disapp. B.D. +23° 540	7·0	,,	13 37 2·80	H.
18	Reapp. 20 Tauri *	4·0	,,	13 42 25·92	H.

The asterisk signifies that the phenomenon occurred at the Moon's bright limb.

The telescopes and clocks used are as follows:—

Guiding Telescope of Astrographic Equatorial	10 inches.	Clock—Dent 2017.
Sheepshanks Equatorial	$6\frac{3}{4}$,,	Earnshaw.
Detached Telescope (Altaz.)	3 ,,	Time tapped on chronograph.

The initials H., A. C., W., W. S., F. J., G. B., are those of Mr. Hollis, Mr. Crommelin, Mr. Witchell, Mr. Stevens, Mr. Jeffries, and Mr. Bartle.

Royal Observatory, Greenwich:
1916 *January* 14.

Occultations of Stars by the Moon, observed at the University Observatory, Warsaw, in the Years 1914–1915. By Professor S. Tscherny.

No.	Date, 1914–1915.	Warsaw Mean Time. h m s	Star.	Mag.	Dis. or Reap.	Telescope.	Observer.
1	Dec. 20	4 56 42·13	Anonyma	9·2	D.	M I.	T.
2	20	5 3 36·03	Anonyma	9·6	D.	M I.	T.
3	Jan. 19	5 45 53·25	B.D. – 3° 5614	...	D.	M I.	T
4	19	6 2 59·44	B.D. – 3° 5620	...	D.	M I.	T.
5	Feb. 21	8 55 47·76	18 Tauri	...	D.	M I.	T.
6	21	8 55 48·19	18 Tauri	...	D.	M II.	S.
7	Mar. 24	6 59 34·60	39 Geminorum	...	D.	M I.	T.
8	24	6 59 34·08	39 Geminorum	...	D.	M II.	S.
9	24	7 14 28·60	Anonyma	8·5	D.	M I.	T.
10	24	7 16 35·60	Anonyma	8·0	D.	M I.	T.
11	24	7 24 23·60	40 Geminorum	...	D.	M I.	T.
12	24	7 24 22·62	40 Geminorum	...	D.	M II.	S.
13	24	7 24 23·25	40 Geminorum	...	D.	L. S.	Sw.
14	24	7 25 43·60	Anonyma	8·5	D.	M I.	T.
15	24	8 10 59·60	39 Geminorum	...	R.	M I.	T.
16	Apr. 19	9 16 25·69	Anonyma	11·0	D.	M I.	T.
17	20	7 53 10·79	Anonyma	8·5	D.	M I.	T.
18	20	8 19 15·51	Anonyma	8·2	D.	M I.	T.
19	20	8 43 13·57	Anonyma	8·0	D.	M I.	T.
20	20	9 12 57·19	Anonyma	8·5	D.	M I.	T.
21	25	9 49 7·79	A. G. Albany 4165?	...	D.	M I.	T.
22	25	9 55 25·29	*d* Leonis	...	D.	M I.	T.
23	25	9 55 24·43	*d* Leonis	...	D.	M II.	S.
24	25	9 55 26·59	*d* Leonis	...	D.	L. S.	Sw.
25	25	11 4 36·29	*d* Leonis	...	R.	M I.	T.
26	25	11 4 35·68	*d* Leonis	...	R.	M II.	S.
27	25	11 4 36·77	*d* Leonis	...	R.	L. S.	Sw.
28	27	8 19 26·49	Anonyma	7·5	D.	M I.	T.
29	May 16	9 9 39·03	112 B Aurigæ	...	D.	M I.	T.
30	16	9 9 37·71	112 B Aurigæ	...	D.	M II.	S.
31	16	9 9 37·92	112 B Aurigæ	...	D.	L. S.	Sw.
32	20	9 13 9·02	Anonyma	9·5	D.	M I.	T.
33	21	9 25 18·97	B.D. + 12° 2108?	...	D.	M I.	T.
34	21	9 31 37·14	B.D. + 12° 2109?	...	D.	M I.	T.
35	22	9 16 28·23	Anonyma	9·6	D.	M I.	T.
36	26	9 5 7·73	Anonyma	7·5	D.	M I.	T.
37	June 21	10 22 16·41	370 B Virginis	...	D.	M I.	T.

Instruments used :—

M I.	162 mm. Merz refractor . . .	Power 94.
M II.	102 mm. Merz-Sabler refractor . .	„ 93.
L. S.	102 mm. Lerebours et Secrétan refractor	„ 60.

Observers :—

T. = S. Tscherny. Sw. = S. Swiderski.
S. = M. Subbotin.

Notes.

Nos. 1, 7, 9, 11, 14, 17, 19, 20, 22, 29, 34, 35, 36, 37 : instantaneous.
Nos. 4, 10, 12, 18, 21, 28, 33 : good.
Nos. 8, 13, 25, 32 : satisfactory.
Nos. 5, 6 : observed through clouds.
Nos. 15, 16 : doubtful.
No. 3 : $\pm 0^{s}\cdot 5$.
Position of Observatory : longitude, $1^{h}\ 24^{m}\ 7^{s}\cdot 25$ E. ; latitude, $52^{\circ}\ 13'\ 4''\cdot 6$ N.

University Observatory, Warsaw :
1915 *July* 6.

Real Paths of 252 *Fireballs and Shooting Stars observed in the British Isles during the Four Years* 1912 *to* 1915 *inclusive.*
By W. F. Denning.

(*Continued from* "*Monthly Notices*," *March* 1912.)

The following list is presented in continuation of similar contributions as under :—

107 meteors in 10 years 1886–96, *M.N.*, January 1897.
429 „ 15 years 1897–1911, *M.N.*, March 1912.

The materials here summarised may, I think, be depended upon, nearly all the observations having been made by those who habitually watch for meteors. Two records of a meteor, if accurately obtained from a pair of stations sufficiently distant, are ample for the derivation of reliable paths, but in certain cases where large fireballs have been widely seen and induced a great number of descriptions of mixed character it has often been very difficult to obtain satisfactory results.

The great majority of the objects included in the table were recorded by Mrs. Fiammetta Wilson (chiefly at Bexley Heath) and Mr. S. A. Wilson, by Miss A. Grace Cook (Stowmarket), and by myself at Bristol. We arranged to look in certain directions offering the best prospect of double or triple observations of

identical meteors. The outcome has been a fairly abundant number of real paths, and among them are many extremely interesting specimens either of fireballs, long-pathed meteors, or meteors from unusual radiants.

Mr. Wilson found it impossible to co-operate with Mrs. Wilson after the breaking out of the war, owing to stress of professional duties occasioned by it; and ill-health has since most unfortunately incapacitated him. Mrs. Wilson has, however, continued her labours with a tireless, whole-hearted enthusiasm which could not fail to bring plentiful results. In all, the table includes 250 meteors, and of these Mrs. Wilson or Mr. Wilson saw 195, Miss Cook 85, and myself 101. Certain objects which were faultily or incompletely observed have been rejected, in fact the time is come when all inaccurate or imperfect observations should be disregarded. They are practically useless. It may just possibly be of some remote utility to record whether a fireball comes from the east or west, but for all exact and scientific ends the data must be obtained by a person who realises what are the essential features to observe and has the ability and will take the trouble to record them. Anyone seeing a meteor should instantly put up his stick (if he is carrying one) on the path and note the line of its direction amongst the stars near it. He should also carefully estimate the duration of flight.

Unless the correct direction is obtained the radiant point cannot be exactly determined. Radiants are very abundant, and they often lie near together, so that unless observations are very precise the individual positions cannot be satisfactorily identified.

Many years ago very discordant values for the heights and velocities of meteors were found. Some were considered to be 200 miles or more above the earth's surface, many others far exceeded 100 miles in elevation; others at the terminal points of their luminous careers were computed as penetrating the air so deeply as to arrive within very few miles of the earth's surface. But there is no doubt that these were abnormal results induced by wild observations.

I believe that no meteors visible to the eye are ever 100 miles in perpendicular height at first appearance, and it is rather doubtful whether any exceed 90 miles. Different showers of meteors group themselves into well-defined families or classes exhibiting remarkable consistency and differing, in fact, very little amongst themselves. But the length of the fiery tracks, the observed velocity, etc., certainly vary according to the altitude of the radiant point above the horizon. The Perseid meteors are usually 75 to 85 miles high at appearance, and 47 to 57 miles high at disappearance, while the Leonids are 2 or 3 miles higher. The swifter meteors are, proportionately with their greater velocity, burnt out at greater heights than the slower ones. A person may, after the experience gained in computing some hundreds of real paths, generally attribute the heights, before investigation, to within a very few miles.

From the large amount of material now accumulated it will be easily possible to ascertain the average values for the elevations, etc., of the various classes of meteors and to find the differences occasioned by the changes in the altitude of their radiants. The lengths of the paths depend enormously upon the latter element, for a number of instances which I examined gave the average length as 215 miles for objects from radiants on or very nearly on the horizon, and an average length of only 25 miles for meteors falling from nearly zenithal radiants! The velocities of the latter seem also greater than those of the horizontal meteors.

A comparison of the radiants will reveal many almost identical positions. Whether these are fortuitous agreements or whether the repeating radiants exemplify long duration must be left for future investigation. My own decided view is that such frequent sequences, like the numerous coincidences derived from the ordinary observation of shower-meteors, must be produced by streams closely associated.

In the ordinary course of nature we should expect many accidental resemblances of place amid such a large aggregate, but the number of those actually found and their practical identity (within the limits of small observational errors) seem to negative the idea that they are the products of mere chance. It remains for the research to be further prosecuted, and again I would insist upon that imperative requirement without which meteoric observation might just as well be abandoned altogether, namely, the greatest *possible accuracy of observation* and the most *careful judgment and discrimination* in the derivation of results such as the radiants and real paths of the objects.

Taking one instance of an apparently recurrent radiant of large meteors included in this or in one of the two preceding lists of real paths, we have the following positions in Sagitta:—

Date.	Radiant.
	° °
1915 April 7	298 + 25
1895 April 19	300 + 20
1914 April 20	302 + 24
1904 June 20	302 + 23
1914 July 11	302 + 23
1912 July 14	300 + 25
1908 July 28	302 + 23
1913 August 3	302 + 25
1915 August 13	300 + 20
1900 October 21	300 + 22
1915 December 12	305 + 21
1910 December 21	301 + 24

Mean radiant of 12 = 301° + 23°

Mean radiant of 22 meteoric showers observed at Bristol, April to October 3, in years 1873 to 1915 = 302° + 22°·25

With regard to that difficult feature stationary radiation, Professor Pickering and the Rev. M. Davidson have written some interesting papers on the subject and in part explained it (*Journal British Astronomical Association*, April and June 1915). But the explanations seem to fail in their *general* application. Professor Pickering assumes that "the great bulk of the showers known lie near the plane of the ecliptic and have direct motion." This is, however, far from being a fact of observation, and so is the shifting (?) radiant of the Leonids, which has never yet been proven.

I would have preferred to let this part of the subject rest after Professor Pickering's and the Rev. M. Davidson's ingenious treatment of the question, but an erroneous impression might have gained ground that the whole thing had been satisfactorily accounted for. This, however, is not admissible; it seem to me that a *comprehensive exposition* of the conditions inducing long duration of certain showers has still to be made.

It is hoped that other amateurs will endeavour to co-operate in acquiring duplicate observations of meteors, and either work in collective groups amongst themselves or in combination with our little community in the south of England. In the large towns of the north such as Liverpool, Manchester, Sheffield, Leeds, etc., observers interested might be found to maintain simultaneous watches of the heavens with a view to recording the flights of identical meteors. Other persons in Wales, Scotland, Ireland, and at places abroad might devote themselves to researches on similar lines. There are ardent astronomical observers everywhere anxious to accomplish something, and here is a field of labour offering special facilities and inducement for successful effort.

The collection of really accurate meteoric data cannot fail to assist future investigations in this branch, and it is one which requires no expensive or elaborate preparation, though it offers much that is attractive from a spectacular point of view.

It cannot but be regretted that so many brilliant fireballs are allowed to escape proper record and inquiry. Certainly more than a million of these attractive objects are annually consumed in our atmosphere, and yet but very few, perhaps 12 or 20, are submitted to discussion and placed on the slab of durable record. In recent years an effort has been made, as it was more than a generation ago by the Luminous Meteor Committee of the British Association, to rescue as many of these beautiful objects as possible from oblivion and to collect all the available data concerning them. My plan has been to write to the newspapers in the district where a fireball has been seen and request observations. In this way useful materials have been sometimes obtained, and it has greatly assisted in the computation of the real paths of the objects.

It is unfortunate that in the case of very large meteors we have frequently to depend wholly or partly upon the impressions of casual observers who may be altogether unacquainted with the essential features to be recorded. Fireballs often appear in

the early evening, during partially cloudy weather or moonlight, when regular observers are not on the alert. The more general co-operation of all classes of the community is therefore desirable in order to obtain data of more abundant and widespread character.

Every student of nature should not only note the principal features of such phenomena whenever they appear in the sky, but should publish a description as early as possible or forward an account to some society or individual known to be interested in the subject. If this plan were generally adopted we should receive many accessions to our data, our sphere of operations would be enlarged, and practical meteoric astronomy in this country would no longer depend upon the exertions of three or four persons forming a sort of "forlorn hope."

Bristol:
1915 *December* 24.

The abbreviations are :—

W.,	Mr. S. A. Wilson or Mrs. Fiammetta Wilson.
A.G.C.,	Miss A. Grace Cook.
W.F.D.,	W. F. Denning.

Cols. 1 and 2 give the date.
3 the hours and minutes of G.M.T.
4 the estimated magnitude.
5 the height in miles of the point of appearance.
6 the height in miles of the point of disappearance.
7 the length in miles of the observed path.
8 the velocity of flight in miles per second.
9 and 10 the R.A. and Dec. of the radiant in degrees.

Date.	G.M.T. h m	Mag.	App. miles.	Dis. miles.	Path. miles.	Vel. m.p.s.	Radiant. α ° δ °
1913 Jan. 1	7 21	>1	71	55	45	18	134+33
,, ,, 2	7 35	♀	85	42	55	15	75+30
,, ,, 9	10 29½	>1	72	45	44	19	353+52
1914 ,, 19	7 4	>☽	51	11	67	14	130+47
1915 ,, 22	6 26	>♃	59	49	82	20	120+ 2
1914 Feb. 5	7 59	♀	50	38	81	40	174+20
1913 ,, 8	8 34	>1	67	43	47	10½	32+ 9
,, ,, 9	6 43	2×♀	48	16	32	...	47+46
1914 ,, 15	10 18½	4½	57	42	19	...	166+30
,, ,, 18	8 20	3–2	78	53	34	17	114+18
1914 Feb. 22	9 27	>1	52	29	23	19	105+53
1915 Mar. 5	9 49	4×♀	62	44	58	24	290+52
1912 ,, 6	8 4	>☽	72	34	295	17	17+ 6
,, ,, 9	8 50	2×♀	67	67	70	20	18+ 9
1914 ,, 18	9 55	3–2	72	43	45	45	247+62
1915 Mar. 21	8 40	>♀	61	27	64	19	28+37
1914 ,, 22	9 8	3	67	61	7	14	100+52
1915 ,, 25	8 36	>♀	66	48	52	16	220+18
1912 ,, 26	9 10	♀–☽	55 62	43 39	133 210	22 28	174–27 208–10
1915 ,, 27	9 13	>1	66	30	42	27	91+59
1915 Mar. 28	7 50½	=☽	71	23	175	21	192+ 4
1912 ,, 28	2 45	>☽	76	26	120	21	2– 2
1914 ,, 31	7 55½	>1	73	29	47	16	130+30
1915 April 5	9 28½	2	71	48	27	18	192+ 4
,, ,, 7	10 22	½=☽	65	49	20	...	180+24
1915 April 7	10 36	>1	69	49	46	20	298+25
,, ,, 8	9 8½	5–2	53	49	24	24	208–10
,, ,, 8	9 51	>1–♃	67	28	46	15	248+70
1912 ,, 8	9 15	>♀	56	40	87	22	210– 8
,, ,, 10	14 33	>☽	51	49	130	10	195–30
1914 April 12	10 5	2–1	64	44	21	18	167+31
1915 ,, 12	11 1	1–>1	65	44	35	27	248+27
,, ,, 14	9 23	1–♃	78	40	38	16	161+57
1914 ,, 15	9 46	4½–2	88	64	49	35	309+61
,, ,, 15	10 22	3–1	71	55	18	36	180+77

Observers.	Notes.
W., W.F.D.	ι Cancrid.
W., C.C.Watson	ι Aurigid.
W., A.G.C.	Compare Nov. 18, 1913.
19 observers	Splendid meteor with loud detonation. Fell to near the earth's surface.
G.H.Willis and others	ζ Monocerotid.
W., M.Smith	Not very certain.
R.O.Williams, W.F.D.	Radiant possibly further west. Slow motion.
Miss M.French, W.F.D., and 3 others	Bright α Perseid. Very low at finish.
W., J.Bunker	Compare April 12, 1914.
W., A.G.C.	Radiant in S.E. region of Gemini.
A.King, W.F.D.	Compare Mar. 22, 1914.
W., F.T.Naish, W.F.Doak, and others	A brilliant κ Cygnid.
11 observers	Very fine object passed over Irish Sea S. to N.
W., A.G.C.	Apparently same radiant as preceding.
W., A.G.C.	η Draconid.
W., A.J.E.Jones, W.J.Wheeler, and others	A very late β Triangulid.
W., A.G.C.	Compare Feb. 22, 1914.
W., A.G.C.	Observations not quite certain.
W. and others	A splendid fireball from a southern radiant.
W., A.G.C.	δ Aurigid.
G.P.B.Hallowes, A.King, and others	Fireball with long flight over English Channel.
6 observers	A splendid meteor visible in afternoon sunshine.
T.H.Astbury, W.F.D.	ι Cancrid.
W., W.F.D.	Same radiant as fireball of Mar. 28, 1915.
W., A.G.C.	Fireball. Observations rather discordant.
W., Miss Gall, and others	Compare April 20, 1914.
W., A.G.C.	α Virginid.
W., W.F.D.	γ Ursæ Minorid.
4 observers	A brilliant α Virginid.
W. and others	A brilliant fireball from radiant far south.
W., W.F.D.	Compare Feb. 15, 1914.
F. Roberts, W.F.D.	A pretty bright ζ Herculid.
S.A.Wilson, W.F.D.	β Ursæ Majorid.
W., P.O.Wright	α Cepheid.
W., A.G.C.	κ Draconid.

Date.	G.M.T. h m	Mag.	App. miles.	Dis. miles.	Path. miles.	Vel. m.p.s.	Radiant. α ° δ °
1914 April 15	10 44	1	73	57	29	29	312+62
1915 ,, 17	11 8¼	1	52	41	11	11	162+58
,, ,, 18	11 6½	1 – ♀	72 65	48 39	35 34	23 21	220+14 200+11
1914 ,, 19	9 45	> ♀	57	38	54	16	76+31
,, ,, 20	11 6	> 1	80	68	105	34	302+24
1914 April 20	10 47	1	72	52	39	30	235± 0
,, ,, 20	12 11	3 – 2	71	54	19	35	230+39
1915 ,, 20	12 56¾	1	62	47	19	17	192+31
1914 ,, 22	10 51	2	76	44	76	24	238– 2
1913 ,, 22	10 22½	2 – 1	79	61	36	...	271+33
1913 April 23	10 9¾	5 – 2	46	46	32	32	260–12
1915 May 2	14 19½	3	76	57	30	45	246+ 2
,, ,, 2	15 2	3 – 2	48	40	15	37	335– 2
,, ,, 5	14 52	♃	69	59	80	40	339– 2
,, ,, 7	9 38	4 – 1	54	40	14	18	174+41
1915 May 7	10 16	4 – 3	54	54	28	28	262–15
,, ,, 7	10 17	3 – 1	63	49	17	21	232+34
,, ,, 7	10 53	3	61	55	27	48	261+ 2
,, ,, 11	11 2	3 × ♃	67	32	64	32	246+ 2
1914 ,, 17	11 52	5 – 3	71	47	24	34	219+40
1914 May 18	10 38	Sirius – Mars	82	56	84	24	271– 2
,, ,, 18	11 20	2	52	35	21	42	262+14
,, ,, 19	10 52	1	48	42	15	15	121+32
1915 ,, 19	9 55	♃	53	53	60	24	278–12
1914 ,, 20	11 15	4 – 2	84	69	47	47	332+36
1913 May 24	11 24½	4 – 3	64	44	24	19	230+17
1915 ,, 31	11 10	1	98	76	24	24	232+26
1914 ,, 31	10 14	♂ – ♃	75	31	49	24	256+36
,, June 3	10 30	♀	51	48	160	25	281–25
1915 ,, 6	10 9	2 × ♀	59	31	31	24	302+78
1915 June 6	10 13½	♀	71	31	49	22	220+13
1913 ,, 14	8 5	> ☽	77	29	58	22	263+64
1913 ,, 14	10 2	2 × ♀	54	54	490	26	282–23
1914 ,, 15	11 4½	4 – 1	60	52	26	19	260–22
,, ,, 15	11 8½	2	87	62	68	35	279–13

Observers.	Notes.
W., A.G.C.	α Cepheid.
W., A.G.C.	β Ursæ Majorid. Radiant near zenith.
W., A.G.C.	Compare June 6, 1915.
W.F.D.	There are rich April showers at both these points.
W.L.Fox, H. Ellis	ι Aurigid.
A.G.C., T.E.R.P., W.H.Steavenson, Greenwich	Compare April 7, 1915.
W.H.Steavenson, Greenwich	Compare April 22, 1914.
A.G.C., Greenwich	μ Coronid.
W., Greenwich	β Comæ Berenicid.
A.G.C., W.F.D.	Compare April 20, 1914.
W., A.G.C.	α Lyrid.
W., A.G.C.	Compare May 7, 1915.
W., F.LeRoy	Compare May 11, 1915.
W., F.LeRoy	An Aquarid of Halley's Comet.
W., F.LeRoy	A fine Aquarid of Halley's Comet.
W., A.G.C.	Rather uncertain.
W., A.G.C.	Compare April 23, 1913.
W., A.G.C.	θ Coronid.
W., A.G.C.	β Ophiuchid.
W. and others	Compare May 2, 1915.
W., A.G.C.	γ Boötid.
W., A.G.C.	Compare June 27, 1913.
W., A.G.C.	α Ophiuchid. Streak.
W., A.G.C.	Rather bright, but slow, short-pathed β Geminid.
W., J.E.Clark	Compare June 15, 1914.
W., W.F.D.	π Pegasid.
W., W.F.D.	β Serpentid.
W., A.G.C.	A pretty bright α Coronid, abnormal height.
E.M.Nelson, F.Denning	A bright π Herculid. Trained.
W., K.Gravely	Compare with June 14, 1913.
W., A.G.C.	A brilliant κ Cepheid.
W. and others	Compare April 18, 1915.
W.Doberck, R.Lines, and 57 others	Observed in sunshine.
Rev. A.D.Taylor and 17 others	A splendid meteor. Compare June 3, 1914.
W., W.F.D.	Compare June 25, 1914.
W., W.F.D.	Compare May 19, 1915.

Date.	G.M.T. h m	Mag.	App. miles.	Dis. miles.	Path. miles.	Vel. m.p.s.	Radiant. α δ
1914 June 15	11 32	6–4	69	53	27	41	315+21
1913 ,, 16	10 48½	2×♃	52	45	38	...	50+46
,, ,, 16	11 0	2–1	69	43	29	29	270+50
1912 ,, 16	11 14	♃	59	29	30	10	270+47
1914 ,, 18	11 19	3–4	60	49	15	28	314+47
1915 June 19	11 7	3–2	61	57	6	28	310+45
,, ,, 19	11 15	5–4	60	52	20	27	320+13
1914 ,, 21	11 22	3–4	72	48	37	37	293+10
,, ,, 25	10 51½	>1	48	44	14	20	260–24
,, ,, 25	11 27½	♀	51	25	45	30	342+39
1914 June 25	11 52½	1–♃	59	23	46	18	354+77
,, ,, 25	11 46	5–4	68	48	39	25	258+2
,, ,, 25	11 57½	♃	67	67	52	52	350–8
,, ,, 26	11 11½	4–2	78	67	11	25	260+70
,, ,, 26	11 17¾	4–2	75	56	22	44	320+61
1913 June 27	11 36	4–3	64	54	20	28	270–6
1914 ,, 29	11 25	1	64	53	19	26	320+19
1915 July 5	8 30	>♀	57	28	260	20	152–6
1913 ,, 10	10 17¼	☽	66	46	74	...	254–22
1914 ,, 11	10 41½	3–1	70	46	31	36	302+23
1912 July 14	11 5	♀	68	49	21	26	300+25
,, ,, 15	10 30	3	69	55	19	24	60+87
1915 ,, 15	10 20½	>1	80	61	42	52	13+48
,, ,, 15	11 30½	2	79	60	30	30	15+48
1914 ,, 17	11 15	2–1	76	61	15	21	289+61
1914 July 17	11 40	2	65	42	37	24	296± 0
,, ,, 17	11 10	>1	75	49	32	32	316+30
,, ,, 21	10 45½	4	52	43	12	24	281+9
,, ,, 22	10 34½	1–♃	94	58	49	90	332+31
,, ,, 24	10 10	4½–3	58	52	10½	21	322+2
1914 July 24	10 21½	1	71	55	31	62	20+57
,, ,, 27	10 58½	1–>1	85	56	49	60	26+50
,, ,, 27	11 24½	4–3	94	72	26	32	332+39
1915 ,, 28	10 19	2	65	49	35	27	334+2
,, ,, 28	11 2½	2	82	56	53	42	5+29

Observers.	Notes.
W., W.F.D.	A very faint meteor.
W., A.G.C.	α Perseid.
W., F.Denning	γ Draconid. From same shower as following.
W., Rev. J.Brown	,, ,, ,, preceding.
W., A.G.C.	Compare following, α Cygnid.
W., W.F.D.	A very short flight.
W., W.F.D.	Radiant N.W. ϵ Pegasi.
W., A.G.C.	Compare Aug. 10, 1915, and Aug. 14, 1914.
W., W.F.D.	Compare June 15, 1914.
W., W.F.D.	Bright o Andromedid. Left a streak.
W., W.F.D.	γ Cepheid.
W., W.F.D.	β Ophiuchid.
W., W.F.D.	ψ Aquarid. Left a bright streak.
W., A.G.C.	Very short path.
W., A.G.C.	Correct radiant probably 312+61.
W., W.F.D.	Compare May 18, 1914.
W., W.F.D.	Radiant near ι Pegasi.
17 observers	Observations not very exact. Daylight.
E.W.Newnham and others	A splendid Scorpiid.
W., W.F.D.	Same radiant as following.
W., W.F.D.	A fine flashing Sagittid.
W., W.F.D.	Polarid.
W., W.F.D.	A bright early Perseid.
W., W.F.D.	An early Perseid.
W., W.F.D.	o Draconid.
W., Miss Gall	η Aquilid.
W., Miss Gall	ζ Cygnid.
W., A.G.C.	Aquilid.
W., W.F.D.	Remarkably swift.
W., A.G.C.	Very short path.
W., Miss Gall	δ Cassiopeid, possibly a Perseid. Streak.
A.G.C., W.F.D.	A fine, early Perseid.
A.G.C., W.F.D.	π Pegasid. At unusual height, but observations dependable.
W., W.F.D.	Compare Sept. 4, 1915.
W., W.F.D.	α Andromedid.

Date.	G.M.T. h m	Mag.	App. miles.	Dis. miles.	Path. miles.	Vel. m.p.s.	Radiant. α ° δ °
1914 July 29	10 46	♃	64	43	68	21	326 − 12
,, ,, 30	11 14	1½ − >1	87	64	36	36	8 + 34½
1913 Aug. 3	11 25	> ♀	87	21	66	15	300 + 52 302 + 25
,, ,, 6	10 11	2½	74	42	59	...	40 + 57
,, ,, 6	11 11	4½	50	44	48	...	283 − 21
1913 Aug. 8	10 54	1 − ♃	71	59	51	34	70 + 41
,, ,, 8	11 42	>1	80	49	74	33	42 + 57
1914 ,, 10	9 44½	1	67	56	33	33	45 + 55
,, ,, 10	9 46	1	67	52	31	39	45 + 61
,, ,, 10	11 40½	1½	72	48	33	49	46 + 57
1915 Aug. 10	9 30	1	61	42	44	44	40 + 55
,, ,, 10	9 33	>1	68	52	154	38	40 + 29
,, ,, 10	10 23½	2½ − 2	84	45	52	20	290 + 11
,, ,, 10	11 0½	3 − 2	81	55	63	42	40 + 38
1912 ,, 11	10 48	1	94	51	80	47	46 + 59
1913 Aug. 11	9 58	2 − 1	27	18	12	6	232 + 52
1914 ,, 11	10 20	1 − ♃	89	42	114	57	28 + 36
,, ,, 11	10 57½	2 − 1	69	53	23	35	42 + 57
,, ,, 11	11 2	3 − 1	74	54	35	35	50 + 58
,, ,, 11	11 25	1 − 1	72	48	38	38	47 + 61
1914 Aug. 11	11 45	>1	81	46	55	40	47 + 56
,, ,, 12	8 50	♃	77	48	57	50	48 + 59
,, ,, 12	10 22	1 − Sirius	78	45	59	45	48 + 58
,, ,, 12	10 33½	♀	80	54	48	40	48 + 59
,, ,, 12	10 35½	>1	76	51	55	55	49 + 57
1914 Aug. 12	10 42	1	76	57	23	45	60 + 59
,, ,, 12	10 52½	>1	82	53	31	80	280 + 44
1915 ,, 12	10 16	1 − ♃	78	57	35	47	44 + 56
,, ,, 12	10 18	2½ − 2	74	42	32	16	281 + 43
,, ,, 12	10 18	♃	80	55	67	...	46 + 44
1915 Aug. 12	10 31	>1	68	49	34	50	49 + 55
,, ,, 12	10 44½	2	56	58	192	35	39 + 7
,, ,, 12	10 56	>1	76	59	42	42	42 + 25
,, ,, 12	11 15	♃	86	51	55	44	42 + 59
,, ,, 12	11 28	2 − 1	77	54	32	40	315 + 13

Observers.	Notes.
W., Miss Gall	A bright β Aquarid.
A.G.C., W.F.D.	π Andromedid.
} Rev. W.F.A.Ellison and 6 others	Observations of rather uncertain character.
W., A.G.C.	Perseid.
W., A.G.C.	Compare June 3, 1914, and June 14, 1913.
W., A.G.C., C.L.Brook	η Aurigid. Left bright streak.
A.G.C., W.F.D., C.L.Brook	A rather bright Perseid.
W., J.E.Clark	,, ,, ,,
W., A.G.C.	,, ,, ,,
W., W.F.D.	,, ,, ,,
W., W.F.D.	Perseid.
W., W.F.D., J.S.Palmer	Left a long streak. Extended course.
W., W.F.D., J.E.Clark	Compare Aug. 14, 1914.
W., J.E.Clark	β Perseid.
W.E.Y.James, W.F.D.	A rather bright Perseid.
W., J.E.Clark	Very low in the air. Observations appear very good.
W., J.E.Clark	A brilliant β Triangulid. Long flight.
W., W.F.D.	Perseid.
W., W.F.D.	,,
W., A.G.C.	,,
W., W.F.D.	,,
W., A.G.C.	A bright Perseid in evening twilight.
W., W.F.D.	A bright Perseid.
W., A.G.C., W.F.D., and others	A brilliant Perseid.
W., W.F.D.	Perseid.
W., A.G.C.	A rather bright Camelopardid.
W., W.F.D.	α Lyrid.
A.G.C., F.Roberts	A bright Perseid.
W.F.D., F.Roberts	α Lyrid.
W., E.J.Gheury	A bright α Perseid.
A.G.C., W.F.D.	A bright Perseid.
W., W.F.D.	Radiant just rising. Long flight.
W. and another	Arietid. Uncertain.
A.G.C., W.F.D.	A bright Perseid.
W., W.F.D.	λ Delphinid.

Date.	G.M.T. h m	Mag.	App. miles.	Dis. miles.	Path. miles.	Vel. m.p.s.	Radiant. α ° δ °
1914 Aug. 13	9 52	> ♀	82	51	105	40	44+39
1915 ,, 13	9 16	♀ − ½ ☽	59	29	30	30	244+72
,, ,, 13	10 40	4 − 2	69	46	28	56	300+20
,, ,, 13	10 40	2 − 2	68	51	27	36	332+10
,, ,, 13	10 50	1 · ♂	68	47	43	54	49+58
1915 Aug. 13	11 8	♀ − > ♀	79	55	48	40	54+56
,, ,, 13	11 11	5 − 2	77	50	44	28	343+14
1914 ,, 14	9 34	2 × ♃ − = ♀	85	54	61	61	44+59
,, ,, 14	9 50	> ♃ − > ♀	67	44	31	16	296+10
1915 ,, 14	10 14	4 − 4	67	52	24	25	194+64
1915 Aug. 14	10 36½	2 − ♂	67	61	7	11	302+13
1914 ,, 16	9 11	2	90	61	60	60	56+60
,, ,, 16	9 17	> ♀	72	34	54	18	302+21
,, ,, 16	9 26½	2 − 1	78	54	59	59	54+59
,, ,, 16	9 56	1½ − 1	80	64	42	30	71+52
1914 Aug. 16	10 30	4	43	32	12	24	254+56
,, ,, 16	11 57	> 1 − > ♃	67	12	64	16	279+45
,, ,, 17	9 38	♃ − ♀	88	54	34	...	282+44
,, ,, 17	10 17½	2 − 1	74	54	34	68	53+58
,, ,, 17	10 34	2 − Sirius	64	48	16	32	281+46
1915 Aug. 18	9 59	2 − 1	75	56	39	58	57½+60
,, ,, 18	10 40	3 − 2	59	52	29	58	72+41
,, ,, 19	9 20	♂	85	51	75	37	145+65
1914 ,, 21	10 55	1	66	31	38	28	281+43
1913 ,, 22	9 19	2	48	48	160	10	208− 7
1913 Aug. 25	10 22	4	75	51	24	36	314+45
,, ,, 25	10 41	1	69	62	16	30	348+ 2
,, ,, 25	10 46	· 3	64	54	18	18	348+ 2
,, ,, 25	11 1	4	64	51	29	20	200+55
1914 ,, 28	10 25	1 − ♃	89	58	220	48	76+33
1914 Aug. 29	8 55	2	67	47	20	26	293+51
1915 Sept. 1	9 42	2 − 1	68	27	41	19	281+44
,, ,, 4	8 26½	4 − 2	64	61	28	21	2− 4
,, ,, 4	10 25	3 − 2	71	59	22	22	334− 0
,, ,, 5	10 18	> 1	77	31	57	28	329+32

Observers.	Notes.
W., Miss H.M.Metcalfe	A bright β Perseid.
W., A.King, and others	Fireball over Scotland. Compare Oct. 5, 1915.
W., W.F.D.	Sagittid.
W., W.F.D.	ϵ Pegasid.
W., W.F.D.	A rather late Perseid.
W., W.F.D., and others	A brilliant Perseid. Streak 30 secs.
W., W.F.D.	α Pegasid.
W., A.G.C.	A fine late Perseid.
W., A.G.C., and others	Compare Aug. 10, 1915.
W., A.G.C.	Radiant N. of ϵ Ursæ Majoris.
W., A.G.C.	Very short path and slow motion.
W., A.G.C., W.F.D.	A late Perseid.
J.E.Clark and others	A brilliant Sagittid.
W., A.G.C.	A late Perseid.
W., W.F.D.	Camelopardalid.
W., A.G.C.	μ Draconid.
W.F.D., E.J.Gheury	α Lyrid. Apparently fell to very near earth's surface
W., W.F.D.	Compare Aug. 16, 1914, and others. α Lyrid.
W., A.G.C.	A late Perseid.
W., P.O.Wright.	Compare Sept. 1, 1915, and others.
W., A.G.C.	A late Perseid.
W., W.F.D.	η Aurigid.
W., J.C.Prior.	
W., W.F.D.	Rich shower from this radiant in 1914.
W., H.Corder	A late α Virginid.
W., W.F.D.	A small α Cygnid.
W., W.F.D.	Compare following.
W., W.F.D.	Compare preceding.
W., W.F.D.	A small ζ Ursæ Majorid.
W., A.G.C., W.F.D.	Left a bright streak along an extended path.
W., W.F.D.	κ Cygnid.
W., W.F.D., Rev. M.Davidson	A continuation of radiant seen Aug. 17 and 21, 1914.
W., W.F.D.	ω Piscid.
W., W.F.D.	ζ Aquarid.
W., F.Roberts	η Pegasid.

Date.	G.M.T. h m	Mag.	App. miles.	Dis. miles.	Path. miles.	Vel. m.p.s.	Radiant. α ° δ °
1913 Sept. 6	10 14	4–1	72	48	25	...	304+40
1915 ,, 7	9 45	4–2	59	43	21	19	340+15
1913 ,, 8	9 44	3–2	24	15	17	17	321− 9
,, ,, 8	9 54	4–3	80	62	40	20	21+14
,, ,, 8	10 10	3–2	80	58	38	30	44+37
1914 Sept. 8	8 55	3× ♀	61	26	83	14	348+ 3
1915 ,, 10	9 41	♅	65	56	140	...	74+42 76+33
1913 ,, 11	10 16	>☽	81 71	66	44	...	74+41 76+32
1915 ,, 11	10 20	2–2	84	46	46	92	352+30
,, ,, 12	8 34	1	73	54	57	28	13+ 5
1912 Sept. 15	7 30	♀	78	44	38	19	235+51
1914 ,, 16	9 38	1	57	39	26	14	343+22
1915 ,, 16	10 1	4–2	67	41	29	58	316+76
1913 ,, 21	8 10	2–1	84	55	76	38	44+40
1914 ,, 23	7 55	1	54	26	40	12	345+24
1914 Sept. 23	10 48	2	73	49	38	69	76+56
,, ,, 24	7 56	>1	52	29	40	28	352+ 2
,, ,, 27	10 35	>1	46	31	45	32	192+56
1915 ,, 29	9 32	1½–1	88	64	37	37	194+75
1913 Oct. 1	10 2½	1–>♅	54 69	48 51	12 18	18 27	314−11 351+52
1912 Oct. 2	8 40	1	64	31	37	15	349+39
1915 ,, 4	8 0	3–4	49	40	15	19	347+ 3
,, ,, 4	11 17	2–>1	76	49	43	43	108+54
,, ,, 4	11 42	♅–♀	59	51	29	...	243+42
,, ,, 5	10 56	½☽	82	55	42	35	248+72
1913 Oct. 7	10 35½	½☽	74	52	86	58	105+36
1912 ,, 8	8 32	>1	65	27	57	23	214+64
,, ,, 8	9 0½	>1	81	48	78	18	32+ 8
1914 ,, 11	10 8	2–1	61	41	26	26	4+10
,, ,, 11	10 10½	4	57	53	6½	14	198+71
1915 Oct. 11	7 26	3	60	42	19	38	284+58
1914 ,, 13	8 46	>☽	29	0	49	8	348+ 3
1915 ,, 13	7 47½	1	76	56	102	35	116+48
,, ,, 13	7 54½	1–>1	79	46	33	40	294+57
1913 ,, 16	7 16	1–♅	76	55	320	32	164+34

Observers.	Notes.
W., A.G.C.	
W.F.D., F.Roberts	Compare Aug. 13, 1915.
W., A.G.C.	Very low in the air. Observations good.
W., A.G.C.	θ Cetid.
W., W.F.D., A.G.C.	β Perseid.
W.F.D., W., and others	Possibly connected with Daniel's Comet of 1907.
J.S.Palmer, Rev. J.M.F.Dumphreys	Aurigid. Precise radiant open to doubt.
Rev. W.F.A.Ellison and others	Exact radiant uncertain.
W., W.F.D.	Observed motion remarkably swift.
W., W.F.D., Miss Gall, A.J.Harris	ϵ Piscid.
W.Gatward, W.A.R.	A bright Quadrantid. Observations not good.
W., A.G.C.	Compare Sept. 23, 1914.
W., G.Martin	κ Cepheid.
W., W.F.D.	β Perseid.
F.T.Naish and another	Compare Sept. 16, 1914.
W., A.G.C.	Radiant S. of β Camelopardalis.
W. and another	Radiant near Equator in Pisces.
W., W.F.D.	A bright ϵ Ursæ Majorid.
W.F.D., A.King	Compare Oct. 11, 1914.
W., W.F.D.	Radiant at 351 + 52 probably correct.
W., A.G.C.	ι Andromedid.
W., W.F.D.	Compare Sept. 8, 1914, and Oct. 13, 1914.
W., W.F.D.	Lyncid.
W., A.King, and others	Observations not very certain.
W. and 11 others	Splendid meteor. Left streak for 18 minutes.
F.T.Naish and 5 others	An early Geminid.
W., A.G.C.	A bright α Draconid.
W., W.F.D.	From a well-defined shower at ξ Ceti.
W., A.G.C.	γ Pegasid.
W., A.G.C.	Short path. Compare Sept. 29, 1914.
W., W.F.D.	o Draconid.
57 observers	Fell to the earth W.N.W. of Wigan. Weight 33 lbs.
F.Roberts, W.F.D.	Compare Oct. 13, 1915. Left a long streak.
Miss Gall, P.O.Wright	From a radiant distinct to that of Oct. 11, 7^h, 26^m, 1915.
W.F.D. and 2 others	Long flight. Radiant nearly on horizon.

Date.	G.M.T. h m	Mag.	App. miles.	Dis. miles.	Path. miles.	Vel. m.p.s.	Radiant. α δ
1913 Oct. 22	9 40	3	50	37	23	17	44+ 5
1914 ,, 26	9 1	> ♃	76	44	48	19	41+22
1913 ,, 27	8 23	1 – ♃	52	42	59	19	35–11
,, ,, 27	9 11	3 – 1	61	46	44	48	46+ 4
,, ,, 28	8 11	3 – 2	67	47	24	36	328+73
1913 Nov. 1	8 26	♃	66	47	86	19	240+30
,, ,, 1	9 26	2 – 3	58	51	49	24	72+11
,, ,, 7	9 57	1	54	26	43	18	47+ 6
1915 ,, 10	8 29	> 1	89	52	55	24	40+22
,, ,, 10	8 40	3	86	58	31	31	32+38
1914 Nov. 11	11 13	> ♀	50	32	66	14	279+41
,, ,, 12	10 5½	1	62	46	21	16	320+41
,, ,, 13	7 59	1½ – 1	54	27	61	17	77+31
,, ,, 13	11 15	3 – 2	84	60	41	61	120+34
1915 ,, 14	14 15	2 – > 1	60	51	30	35	61 – 20
1915 Nov. 14	14 17½	2	68	49	19	38	77+48
,, ,, 14	14 49	1 – < ♃	80	52	45	45	149+23
1914 ,, 16	12 11½	4 – 2	65	51	17	34	104+36
,, ,, 16	12 23	1	52	46	9	12	71+10
1913 ,, 18	6 26	3 – 2	72	64	40	26	132+47
1913 Nov. 18	8 28	1	59	42	17	12	351+52
1914 ,, 20	9 58	♀	72	32	40	12	27+44
1913 Nov. 24	8 48	> ☽	77	24	68	20	273+69
1914 ,, 28	7 48½	2 × ♃	65	48	39	26	91+20
1912 Dec. 1	10 36½	1 – ♃	71	43	38	16	53+25
1915 Dec. 3	9 58	♃	71	54	44	30	163+48
1913 ,, 4	9 0¼	☽	54	21	37	11	43+29
1914 ,, 7	8 32	2	55	29	36	...	270+71
,, ,, 8	7 49½	3	45	41	49	9	338–28
,, ,, 8	8 19	4 – 2	60	44	19	13	42+20
1915 Dec. 8	8 44	> 1	88	46	101	60	134+45
1914 ,, 8	8 47	2	65	47	34	25	92+22
,, ,, 8	9 37½	3	63	54	14	28	116+49
1915 ,, 11	9 32	2 – 1	80	44	54	36	108+32
,, ,, 11	10 2	2 – 1	76	45	44	30	108+32

Observers.	Notes.
W., A.G.C.	Compare Oct. 27 and Nov. 7, 1913.
H.J. Bunker, F. Sargent	A bright ϵ Arietid.
W., J.E.Clark, J.L.Haughton	Fine meteor from radiant S. of Mira Ceti.
W., A.G.C., J.L.Haughton	Compare Oct. 22 and Nov. 7, 1913.
W., W.F.D.	A β Cepheid.
W., A.G.C.	A very late Coronid.
W., A.G.C.	Compare Nov. 16, 1914.
W., A.G.C.	Compare Oct. 22 and 27, 1913.
W., A.G.C., Miss Gall	ϵ Arietid.
W., W.F.D.	A late β Triangulid.
Miss Gall and others	A bright α Lyrid.
W., A.G.C.	σ Cygnid.
A.King, W.F.D.	ι Aurigid.
W., W.F.D.	β Geminid. Streak.
W., A.G.C., Miss Gall	γ Eridanid.
W., A.G.C.	Radiant probably close to η Aurigæ.
W., Miss Gall	A bright Leonid.
W., A.G.C.	An early Geminid.
W., A.G.C.	Short path. Compare Nov. 1, 1913.
W., W.F.D.	Compare Dec. 8, 1915.
W., A.G.C.	Compare Jan. 9, 1913.
E.M.Nelson, W.F.D.	One of the Andromedids of Biela's Comet.
H.P.Denning and 4 others	Fireball. Radiant near pole of ecliptic.
H.Illingworth, Mrs. R.M.Brook	Compare 1914 Dec. 8, $9^h\ 47^m$.
W., W.F.D.	Radiant on W. borders of Pleiades.
F.Sargent, F.W.Baker	ψ Ursæ Majorid.
C.Grover, H.G.S.Barrett	Very fine Arietid but only two observations.
W., J.E.Clark	Radiant near pole of ecliptic.
W., A.G.C.	A very late α Piscid. Moved very slowly.
W., W.F.D.	A late ϵ Arietid. Compare Dec. 15, $8^h\ 23^m$.
W., A.G.C.	Very swift.
A.G.C., J.E.Clark	Compare Nov. 28, 1914.
W., A.G.C.	Compare Oct. 13, 1915. Short path.
W., Miss Gall	α Geminid.
W., A.G.C.	,,

Date.	G.M.T. h m	Mag.	App. miles.	Dis. miles.	Path. miles.	Vel. m.p.s.	Radiant. α ° δ °
1912 Dec. 12	8 7	>1	76	49	77	24	118 +32
1915 ,, 12	9 26	1>1	42	27	60	16	305 +21
,, ,, 12	11 23	1>1	68	52	29	29	118 +32
1914 ,, 15	6 25	>1	66	38	71	14	336 −12
1915 ,, 15	8 23	> ♀	65	25	57	28	44 +20
1914 Dec. 29	6 58	2 × ♃	67	46	44	18	261 +61

Observers.	Notes.
W., W.F.D.	β Geminid.
W., A.G.C.	A very late Sagittid. Radiant here April to December.
A. King, F. Roberts	α Geminid.
W., W.F.D.	A very late δ Aquarid.
J. West, W.F.D.	A late ε Arietid.
W. and 4 others	ζ Draconid.

Three Variable Stars in Lacerta. By C. Martin and H. C. Plummer. (Plates 3, 4.)

1. During the last four years Mr. Martin has secured 115 exposures on a certain region in Lacerta with the 15-inch reflector. This region contains two known variables, V and X Lacertæ, and a third star, B.D. $+55^{\circ}\cdot2809$, at first included among the comparison stars, ultimately proved to be variable. V Lacertæ, or B.D. $+55^{\circ}\cdot2815$, was found to be variable by Mme. Ceraski,* and received the provisional number 110·1904. It was studied photometrically at the Laws Observatory,† at first by comparison with B.D. $+55^{\circ}\cdot2817$. This led to the discovery that the latter star is also variable, and it received the provisional number 88·1906 and later the designation X Lacertæ. All the plates of the present series have been measured and reduced by Mr. Martin, according to the method adopted at this observatory and previously described.‡

2. The magnitudes of the comparison stars have been based on two plates exposed under similar conditions, (*a*) on the region of the variables, and (*b*) on the χ Persei cluster. The magnitude scale of these plates is deduced by adopting Schwarzschild's determinations for certain standard stars in the latter region. The results are given in the following table:—

TABLE I.

Star.	B.D.	Plate 992. m_1.	Plate 1009. m_2.	m_2-m_1.	Provisional Mag.
a	$+56^{\circ}\cdot2872$	8·81	8·90	+·09	8·86
b	+55·2814	9·08	9·14	+·06	9·11
c	+55·2823	9·70	9·78	+·08	9·74
d	+55·2818	10·35	10·39	+·04	10·37

Each exposure on the region of the variables gives a set of residuals for the comparison stars. From these are derived the following results:—

Star	*a*	*b*	*c*	*d*
	m	m	m	m
Extreme range . .	·15	·20	·15	·16
Probable error . .	±·018	±·022	±·019	±·017
Mean correction . .	+·013	−·021	−·001	−·004
Final magnitude . .	8·87	9·09	9·74	10·37

Since there are only four comparison stars, owing to the loss of one standard originally chosen, these probable errors for a single

* *A.N.*, 3953.
† *Laws Obs. Bull.*, Nos. 8, 10, 13.
‡ *M.N.*, lxxiii. pp. 166, 440.

exposure are doubtless too favourable a measure of the accuracy attained. Yet, coupled with the extreme range of error found in over a hundred exposures, they give ample assurance that the four stars are sensibly constant in magnitude. The final corrections to the adopted magnitudes are satisfactorily small, and call for no revision in the case of the variables.

3. For V Lacertæ the elements of maximum

$$\text{J.D. } 241\ 6666{\cdot}76 + 4{\cdot}98269\,\text{E}$$

were determined at the Laws Observatory. For the Dunsink observations a maximum at the epoch J.D. 242 0050·456 was adopted. This gives an interval of 679 periods, and the Laws epoch, according to the above elements, then precedes the Dunsink epoch by $0^d{\cdot}45$. The curve is characteristic of the δ Cephei type, with a well-defined maximum, and this discrepancy cannot be admitted. We infer that the period has lengthened in the interval by $0^d{\cdot}000662$, and adopt for the elements of maximum

$$\text{J.D. } 242\ 0050{\cdot}456 + 4{\cdot}983352\,\text{E}.$$

These elements satisfy the Dunsink observations well, and may be taken to refer to the mean epoch 1914·5. The correction to these elements is about $+0^d{\cdot}000001\,\text{E}$ for the period, and therefore about $+0^d{\cdot}0000005\,\text{E}^2$ for the epoch of maximum.

4. The question of the elements to be adopted for X Lacertæ is not quite so simple. The Laws Observatory elements for minimum are

$$\text{J.D. } 241\ 6672{\cdot}45 + 5{\cdot}44269\,\text{E}.$$

A provisional minimum was adopted for the Dunsink observations at J.D. 241 9748·56, giving an interval of 3076·11 days corresponding to 565 periods. According to this the Laws epoch precedes the Dunsink epoch by $0^d{\cdot}99$, and an increase of $0^d{\cdot}00175$ in the period is required. But this correction can hardly be accepted without further examination. The Laws observers preferred to adopt an epoch of minimum, because the maximum was ill-defined. The Dunsink observations equally fail to define the maximum. But, according to the latter, the minimum is exceptionally flat, and not at all suited to define a reference point. A consideration of the bearing of the later observations at the Laws Observatory on the position of minimum, and of the two corresponding epochs of maximum, suggested that the Laws period might really require no great change. To test this, the Dunsink observations on the steep ascending branch (which is alone suitable for the purpose) were reduced with a period (5·4429) very near the Laws period. The evidence then showed quite consistently that the observations were thrown out of line by $^d{\cdot}103$ per year, or that they required an increase of $^d{\cdot}00154$ in the period. This agrees exactly with the above correction, and we adopt as the elements of maximum

$$\text{J.D. } 241\ 9750{\cdot}55 + 5{\cdot}444442\,\text{E}$$

about the mean epoch 1914·5. The secular correction to the period is about $+0^{d}\cdot000003E$, and to the epoch about $+0^{d}\cdot0000015E^{2}$. As all the observations fall within a time less than 12 years, it is only possible to indicate the order of magnitude of these secular variations both in the case of V and X Lacertæ. They certainly seem very considerable.*

5. The curve drawn for V Lacertæ (fig. 1) is based on the formula

$$\begin{aligned} m = 9\cdot84 &+ \cdot58\sin(\theta+229^{\circ}) + \cdot21\sin(2\theta+260^{\circ}) \\ &+ \cdot12\sin(3\theta+294^{\circ}) + \cdot07\sin(4\theta+265^{\circ}) \\ &+ \cdot05\sin(5\theta+317^{\circ}) \end{aligned}$$

where, t being the time after the preceding maximum and P the period,

$$\theta/2\pi = t/\mathrm{P}.$$

The formula is derived from the analysis of 24 equidistant ordinates. Clearly little gain would accrue to the representation by adding higher harmonics with smaller coefficients. The curve and formula bear a resemblance to those found for RR Lyræ † which seems more than superficial.

6. Similarly, the curve drawn for X Lacertæ (fig. 2) is based on the formula

$$\begin{aligned} m = 9\cdot28 &+ \cdot30\sin(\theta+218^{\circ}) + \cdot08\sin(2\theta+235^{\circ}) \\ &+ \cdot04\sin(3\theta+173^{\circ}) + \cdot05\sin(4\theta+311^{\circ}) \\ &+ \cdot04\sin(5\theta+227^{\circ}) \end{aligned}$$

and again the higher harmonics are negligible. It may seem that the observations do not warrant the character assigned to the curve in the neighbourhood of maximum. But this is imposed by the formula, and not assigned in any arbitrary manner. It is to be justified in the same way as drawing a horizontal straight line or a simple sine curve in the absence of definite evidence that the curve is more complicated. Here the curve drawn is the *simplest* harmonic representation of the variation throughout a period.

7. Except in cases where a plate has been rejected on preliminary inspection owing to the inferior quality of the images, all the measures of the variables have been entered in the table of observations and plotted on the diagrams. A residual of

* It will be noticed that in both cases the period which suits the Dunsink observations alone agrees with that required to reconcile the two epochs, *i.e.* corresponds with the period appropriate to the intermediate epoch between the two series. This is not as it should be. For X Lacertæ it is not surprising, on account of the difficulty in identifying corresponding epochs, and in either case the whole time covered is small. For this reason an accurate determination of the variation is not yet possible, even assuming that it is really secular and not periodic, as often supposed, or discontinuous, as suggested by Professor Turner in the case of long-period variables. Here of course, in spite of the short interval of twelve years, we are dealing with hundreds of periods.

† *M.N.*, lxxv. p. 566.

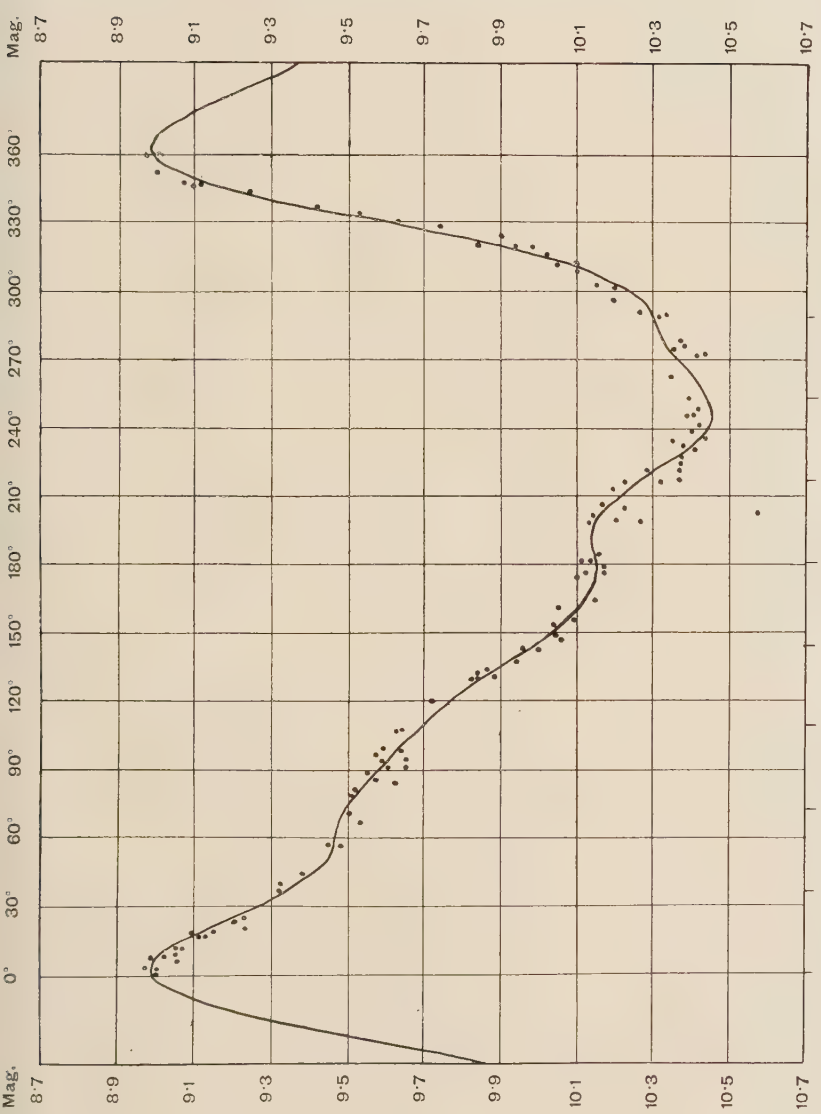

Fig. 1.—Photographic Light Curve of V Lacertæ.

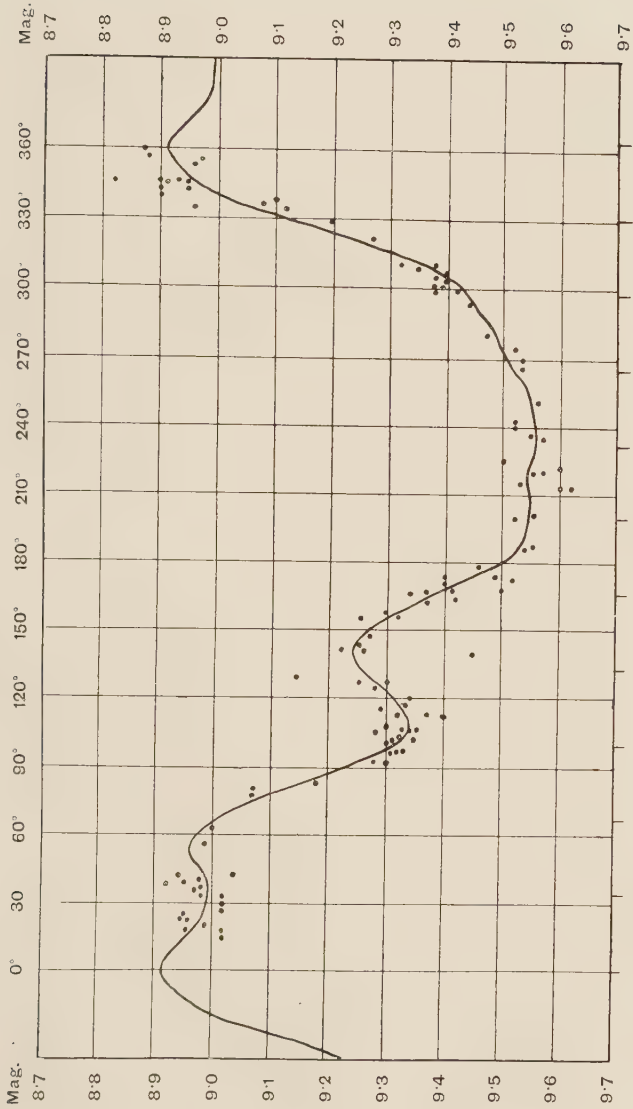

Fig. 2.—Photographic Light Curve of X Lacertæ.

+·39 among the observations of V Lacertæ and one of +·21 among those of X Lacertæ may be noticed. Such anomalies among 115 exposures are scarcely surprising, and are probably to be attributed to abnormal local inequalities in the film. If these two be ignored, the average deviation of a measure from the curve drawn is $\pm^{m}\cdot034$ in the case of both stars alike, and the probable error of a single measure may be taken to be $\pm^{m}\cdot03$, a figure which accords with previous experience of similar work at Dunsink.

8. A curve has been given to represent the photometric observations of V Lacertæ at the Laws Observatory (*loc. cit.*, p. 210). The photometric range is $0^{m}\cdot95$ as compared with the photographic range 1·48, giving a ratio of 1·56 for the latter. The photometric minimum follows the maximum at an interval of 3·33 days, and the corresponding interval in the photographic curve is about 3·4 days and therefore in good agreement. The sinuosities in the descending branch of the photographic curve have been ignored in drawing the visual curve, but the deviations of the normal places from the curve which is based on them closely confirm the way in which the photographic curve is now drawn.

9. A curve has also been given to represent the photometric observations of X Lacertæ (*loc. cit.*, p. 113), though this is based on preliminary work and seems distinctly capable of revision. The visual range, which later observations suggest to be rather underestimated, is $0^{m}\cdot36$ as compared with the photographic range $0^{m}\cdot65$, giving a ratio of 1·81 for the latter. The photometric minimum follows the maximum at an interval of 3·0 days, while the corresponding interval in the photographic curve is 3·6 days. But no significance attaches to the difference, owing to the nature of the curves. The small visual range sets a difficult task for photometric observers, and the general similarity to be noticed in the broad features of the photometric and photographic curves is perhaps all that can be expected. The irregularities in the descending branch of the photographic curve are missed in the visual curve, but the mean deviations shown by the later work suggest that a careful reduction of the whole series of photometric observations would bring to light similar fluctuations in this part of the visual light curve also.

10. The star B.D. +55°·2809 was selected as a comparison star, but proved to be variable. Its deduced magnitudes are entered in the table of observations, and show a range of half a magnitude, from 9·3 to 9·8 (photographic). We have found no period, and conclude that its variation is irregular in type. Beyond the importance of detecting those stars which are unsuitable as standards of comparison, this is probably not in itself a very interesting object. The chief point of interest is the confirmation it lends to our suspicion that about one in every five stars in the neighbourhood of the ninth magnitude is variable to a measurable extent. This is a considerably higher estimate than seems to be generally entertained.

11. The results from the individual observations are given in

Table II. In the first column is the date and G.M.T. for the middle of the exposure. The second column gives the corresponding Julian Day and decimal fraction, and the third gives the length of exposure in minutes. The next three columns refer to V Lacertæ. They give the phase in days based on the elements of maximum adopted in § 3, the deduced photographic magnitude of the variable, and the deviation of this observed magnitude from the curve (fig. 1) representing the formula given in § 5. Similarly, the next three columns refer to X Lacertæ, and give the phase in days based on the elements of maximum adopted in § 4, the photographic magnitude of the variable, and the deviation of the latter from the curve (fig. 2) representing the formula given in § 6. The last column of the table gives the deduced photographic magnitude * of the new variable B.D. + 55°·2809.

TABLE II.

Date G.M.T.	Julian Day.	Exposure.	V Lacertæ.			X Lacertæ.			B.D. +55°·2809.
			Phase.	Mag.	O − C.	Phase.	Mag.	O − C.	Mag.
1912 Sept. h m	2419	min.	d			d			
17 10 8	663·422	30	1·67	9·71	− ·06	5·43	8·87	− ·04	9·61
Oct.									
9 10 52	685·453	30	3·77	10·43	+ ·04	0·24	8·96	·00	9·55
9 12 55	685·538	30	3·85	10·37	+ ·04	0·32	8·96	− ·02	9·43
10 10 13	686·426	30	4·74	9·24	+ ·02	1·21	9·07	− ·06	9·47
14 7 3	690·294	30	3·63	10·34	− ·06	5·08	9·08	+ ·03	9·48
14 10 10	690·424	30	3·75	10·42	+ ·06	5·21	8·82	− ·14	9·38
18 9 58	694·416	30	2·76	10·20	+ ·05	3·75	9·53	+ ·02	9·46
31 9 17	707·387	35	0·78	9·48	+ ·02	0·39	9·02	+ ·03	9·60
Nov.									
1 9 10	708·381	35	1·78	9·84	·00	1·39	9·28	+ ·02	9·45
1 10 56	708·456	35	1·85	9·86	− ·02	1·46	9·33	+ ·03	9·51
7 8 1	714·334	30	2·75	10·13	− ·02	1·90	9·25	− ·03	9·69
11 8 45	718·365	30	1·79	9·83	− ·01	0·48	9·02	+ ·03	9·58
12 9 51	719·411	24	2·84	10·22	+ ·04	1·53	9·31	− ·02	9·62
13 8 46	720·365	35	3·79	10·35	+ ·01	2·48	9·42	+ ·06	9·52
13 13 42	720·572	30	4·00	10·33	+ ·03	2·69	9·46	− ·04	9·60
30 10 16	737·428	30	0·92	9·53	+ ·06	3·21	9·62	+ ·07	9·60
Dec.									
2 7 30	739·313	36	2·81	10·56	+ ·39	5·10	9·10	+ ·08	9·61
6 7 30	743·313	35	1·82	9·88	+ ·02	3·65	9·52	− ·04	9·67

* The symbol ϕ has recently been suggested by Mr. Bellamy for photographic magnitude. Unfortunately, the chief antithesis is photometric magnitude. Hence ϕ has no special appropriateness. But symbols expressing the different kinds of magnitude, the number of which always tends to increase, would be useful.

TABLE II.— *ontinued.*

Date G.M.T.	Julian Day.	Exposure.	V Lacertæ. Phase.	Mag.	O−C.	X Lacertæ. Phase.	Mag.	O−C.	B.D. +55°2809. Mag.
1912 Dec. h m	2419	min.	d			d			
9 6 25	746·268	35	4·78	9·10	−·05	1·16	9·07	−·03	9·55
11 10 16	748·428	30	1·96	9·96	·00	3·32	9·57	+·02	9·42
16 8 34	753·357	30	1·90	9·94	+·02	2·81	9·55	+·02	9·62
1913 Jan.									
1 6 1	769·251	30	2·85	10·16	−·03	2·37	9·30	−·01	9·35
July									
29 11 0	978·458	35	2·75	10·27	+·12	4·69	9·38	+·02	9·55
Aug.	2420								
25 10 22	005·432	35	4·81	9·07	−·05	4·44	9·44	−·01	9·84
26 9 22	006·390	30	0·78	9·45	−·01	5·40	8·88	−·04	9·58
27 9 37	007·401	30	1·80	9·84	−·01	0·96	9·00	·00	9·59
28 9 13	008·384	30	2·78	10·15	−·01	1·95	9·14	−·13	9·60
28 13 40	008·570	30	2·96	10·19	−·05	2·13	9·22	−·02	9·53
Sept.									
3 9 55	014·413	35	3·82	10·38	+·05	2·53	9·50	+·10	9·55
9 8 50	020·368	30	4·80	9·11	−·04	3·04	9·55	·00	9·50
9 12 49	020·534	30	4·96	8·97	−·02	3·21	9·60	+·05	9·48
29 8 46	040·365	30	4·86	9·00	−·07	1·26	9·18	·00	9·49
Oct.									
9 12 0	050·500	30	0·04	8·97	−·02	0·51	8·97	−·02	9·29
9 13 19	050·556	30	0·10	8·99	·00	0·56	8·92	−·07	9·32
9 13 49	050·576	30	0·12	9·05	+·04	0·58	8·95	−·04	9·35
21 9 24	062·392	30	1·97	10·00	+·03	1·51	9·30	−·02	9·40
21 10 59	062·458	30	2·04	10·06	+·05	1·57	9·28	−·05	9·35
21 11 39	062·486	30	2·06	10·04	+·02	1·60	9·33	−·01	9·33
21 14 1	062·584	30	2·16	10·09	+·01	1·70	9·37	+·03	9·37
22 9 59	063·416	30	2·99	10·22	−0·4	2·53	9·41	+ 01	9·33
22 11 29	063·479	30	3·06	10·28	−·02	2·60	9·52	+·08	9·33
22 12 4	063·503	30	3·08	10·37	+·06	2·62	9·49	+·04	9·33
23 10 7	064·421	30	4·00	10·31	+·01	3·54	9·57	+·01	9·37
23 10 40	064·445	30	4·02	10·26	−·04	3·56	9·55	−·01	9·29
23 12 28	064·520	30	4·10	10·19	−·08	3·64	9·52	−·04	9·28
24 9 32	065·397	30	4·97	8·98	00	4·51	9·38	−·05	9·39
24 10 3	065·419	30	0·01	9·00	+·01	4·54	9·39	−·03	9·33
24 12 18	065·513	30	0·11	9·02	+·02	4·63	9·40	+·01	9·33
29 9 33	070·398	30	0·01	9·00	+·01	4·07	9·53	+·03	9·40
29 11 30	070·479	30	0·09	9·05	+·06	4·15	9·52	+·03	9·49
29 13 1	070·543	30	0·15	9·07	+·04	4·22	9·47	−·02	9·48

TABLE II.—*continued.*

Date G.M.T.	Julian Day.	Exposure.	V Lacertæ.			X Lacertæ.			B.D. +55°·2809.
			Phase.	Mag.	O−C.	Phase.	Mag.	O−C.	Mag.
1913 Oct. h m	2420	min.	d			d			
30 9 19	071·389	30	1·00	9·50	+·01	5·06	8·96	−·10	9·43
30 10 54	071·455	30	1·07	9·52	00	5·13	8·90	−·10	9·43
30 11 25	071·476	30	1·09	9·52	−·01	5·15	8·90	−·09	9·45
30 13 13	071·551	30	1·16	9·62	+·07	5·21	8·93	−·03	9·48
Nov.									
21 7 27	093·311	30	2·99	10·32	+·06	5·21	8·95	−·01	9·59
21 7 57	093·332	30	3·01	10·37	+·10	5·23	8·90	−·06	9·61
Dec.									
23 9 7	125·379	30	0·17	9·05	+·01	4·61	9·38	−·02	9·50
23 10 30	125·438	30	0·23	9·11	+·02	4·67	9·35	−·02	9·37
23 11 1	125·459	30	0·25	9·15	+·03	4·69	9·32	−·04	9·43
30 6 51	132·286	30	2·10	10·05	00	0·63	8·94	−·05	9·32
31 6 52	133·286	30	3·10	10·37	+·04	1·63	9·30	−·04	9·41
31 8 11	133·340	30	3·15	10·37	00	1·68	9·40	+·06	9·34
31 9 32	133·397	30	3·21	10·40	00	1·74	9·29	−·04	9·40
31 10 16	133·428	30	3·24	10·35	−·06	1·77	9·33	00	9·40
914 Jan.									
26 6 58	159·291	35	4·18	10·20	−·01	0·41	9·02	+·03	9·45
26 8 46	159·365	35	4·26	10·10	−·04	0·48	8·98	−·01	9·30
26 10 12	159·425	35	4·32	10·05	00	0·54	8·98	−·01	9·35
Oct.									
19 9 40	425·403	30	1·20	9·57	+·01	5·19	8·95	−·03	9·65
19 10 11	425·424	30	1·22	9·55	−·03	5·21	8·91	−·05	9·50
Nov.									
10 8 29	447·354	40	3·21	10·38	−·02	5·36	8·97	+·05	9·50
17 8 11	454·340	45	0·23	9·10	00	1·46	9·32	+·02	9·53
26 6 45	463·282	30	4·19	10·15	−·05	4·95	9·20	+·06	9·57
Dec.									
7 6 17	474·262	35	0·22	9·12	+·03	5·05	9·12	+·05	9·45
8 6 56	475·289	45	1·25	9·60	+·02	0·63	9·04	+·05	9·60
9 6 28	476·270	45	2·23	10·05	−0·5	1·61	9·35	+·01	9·44
1915 Sept.									
3 10 48	744·451	45	1·31	9·65	+·04	3·01	9·52	−·03	9·74
7 9 49	748·409	45	0·28	9·23	+·09	1·53	9·35	+·03	9·57
7 10 35	748·442	45	0·32	9·20	+·01	1·56	9·33	00	9·70
7 11 26	748·476	45	0·35	9·23	+·04	1·59	9·34	00	9·71
8 9 17	749·387	45	1·26	9·65	+·07	2·50	9·34	−·05	9·55
8 10 3	749·419	45	1·29	9·59	−·01	2·54	9·37	−·03	9·52

TABLE II.—*continued.*

Date G.M.T.	Julian Day.	Exposure.	V Lacertæ. Phase.	Mag.	O−C.	X Lacertæ. Phase.	Mag.	O−C.	B.D. +55°.2809. Mag.
1915 Sept. h m	2420	min.	d			d			
8 10 57	749·457	45	1·33	9·57	−·04	2·57	9·40	−·03	9·54
8 11 43	749·489	45	1·36	9·64	+·01	2·61	9·40	−·05	9·64
10 9 43	751·406	45	3·28	10·43	00	4·52	9·42	−·01	9·75
10 10 29	751·438	45	3·31	10·40	−·04	4·56	9·38	−·04	9·74
10 11 23	751·474	45	3·35	10·42	−·03	4·59	9·40	−·01	9·66
11 12 58	752·541	45	4·42	9·94	+·05	0·21	9·02	+·06	9·26
13 11 44	754·490	22	1·38	9·59	−·05	2·16	9·25	+·01	9·39
29 8 15	770·343	45	2·28	10·15	+·03	1·68	9·32	−·02	9·62
29 11 11	770·465	45	2·41	10·10	−·05	1·80	9·34	+·03	9·49
29 12 58	770·541	45	2·48	10·17	+·02	1·88	9·28	−·01	9·50
29 13 53	770·579	45	2·52	10·11	−·04	1·92	9·30	+·02	9·41
30 11 3	771·460	45	3·40	10·39	−·06	2·80	9·54	−·01	9·36
Oct.									
4 11 35	775·483	45	2·44	10·12	−·03	1·38	9·30	+·05	9·53
4 13 23	775·558	45	2·52	10·13	−·02	1·45	9·31	+·02	9·58
5 10 34	776·441	45	3·40	10·40	−·05	2·34	9·25	−·05	9·44
5 11 24	776·475	45	3·43	10·42	−·03	2·37	9·32	+·01	9·40
5 13 11	776·549	45	3·51	10·39	−·05	2·44	9·37	+·02	9·31
6 8 12	777·341	45	4·30	10·10	00	3·24	9·53	−·02	9·79
6 10 0	777·417	45	4·37	10·02	+·03	3·31	9·55	00	9·75
6 10 59	777·458	45	4·42	9·98	+·10	3·35	9·60	+·05	9·42
6 11 45	777·490	45	4·45	9·84	00	3·38	9·50	−·05	9·30
14 13 20	785·556	50	2·55	10·15	+·01	0·56	8·98	−·01	9·40
Nov.									
1 10 25	803·435	45	0·49	9·32	−·01	2·11	9·45	+·21	9·60
1 11 15	803·468	45	0·53	9·32	−·04	2·14	9·26	+·02	9·52
1 13 9	803·548	45	0·61	9·38	−·03	2·22	9·27	+·02	9·56
10 11 4	812·461	40	4·54	9·74	+·10	0·24	9·02	+·06	9·50
10 11 59	812·499	45	4·57	9·63	+·04	0·28	8·99	+·02	9·57
10 12 54	812·538	45	4·61	9·53	+·05	0·32	8·95	−·03	9·53
10 13 52	812·578	45	4·65	9·42	+·02	0·36	8·95	−·03	9·40
30 8 2	832·334	35	4·48	9·90	+·12	3·78	9·56	+·01	9·54
Dec.									
7 7 40	839·320	45	1·49	9·64	−·05	5·33	8·96	+·03	9·48
8 6 22	840·265	45	2·44	10·17	+·02	0·83	8·99	+·03	9·43
12 6 59	844·291	45	1·48	9·63	−·05	4·85	9·27	+·03	9·39

Dunsink Observatory:
1916 *Jan.* 11.